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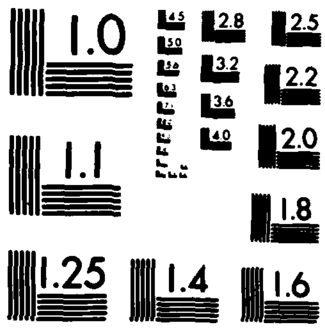

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U.S. Department
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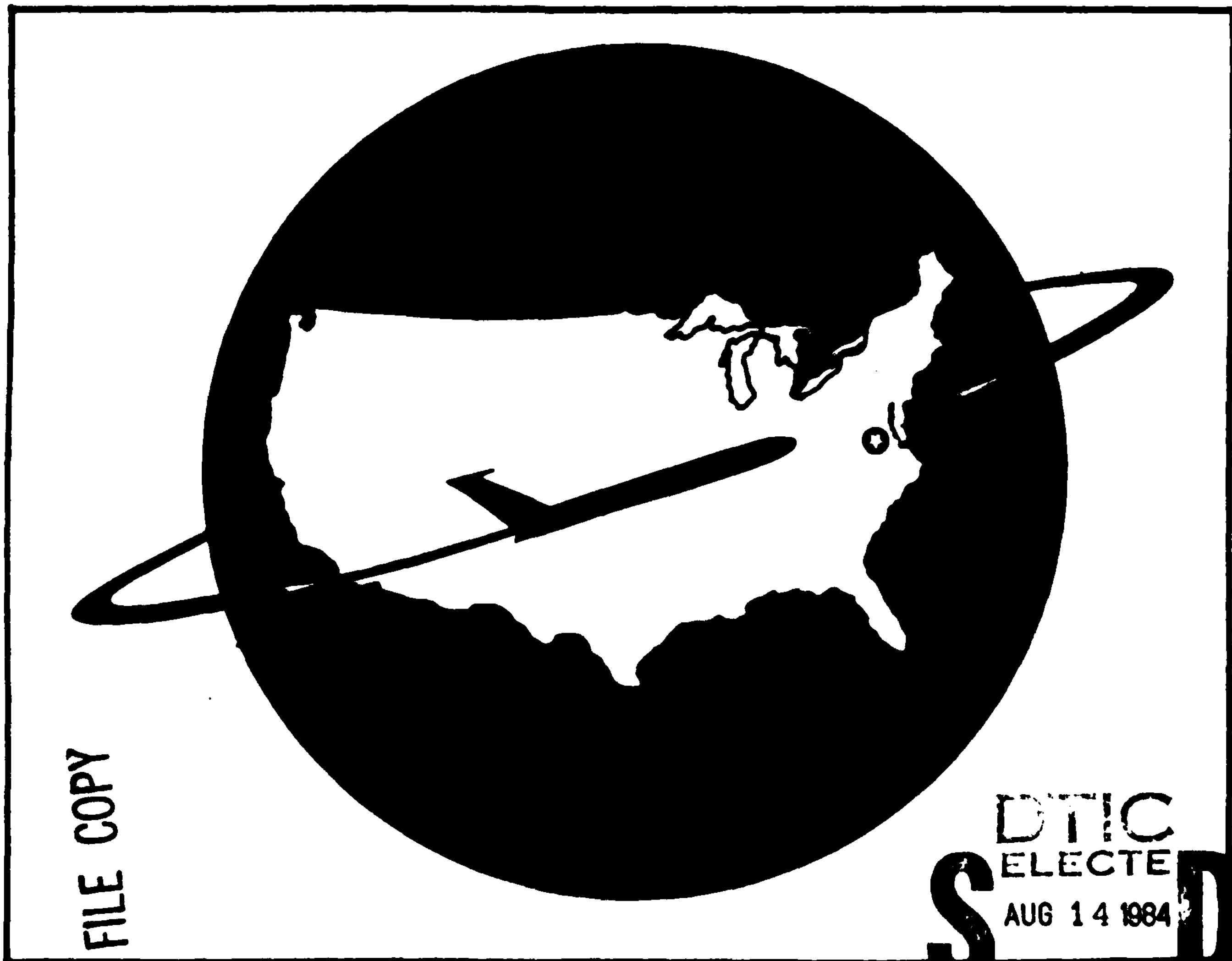
NATIONAL AIRSPACE REVIEW

Benefits and Costs

Report No. DOT/FAA/AT-84/1

By
Engineering & Economics
Research Inc.



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16. Abstract

Three of the twenty enhancement areas identified for implementation within the National Airspace Review (NAR) are evaluated as to their benefits and costs. These areas are Airport Radar Service Area (ARSA), ARTCC Resectorization, and the Random Routes aspect of area navigation (RNAV) Integration. A methodological approach to evaluation of benefits anc costs, suitable for application to all enhancement areas, is developed. Each of the three areas covered in this report is treated in detail in the report and supported by quantitative data placed in appendices.

Two other reports should be considered in conjunction with this report: the NAR Interim Report and the NAR Implementation Plan. Updates of this report are anticipated each six months.

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NATIONAL AIRSPACE REVIEW BENEFITS AND COSTS

by

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Prepared for

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May 1984

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EXECUTIVE SUMMARY

The National Airspace Review (NAR) is a cooperative venture of the aviation industry and government. Using a synergistic approach, the NAR is comprehensively reviewing air traffic control procedures, flight regulations, and airspace for the purpose of validating the current system or identifying near-term changes which will promote greater efficiency. As a component of the *National Airspace System Plan (NAS Plan)*, the NAR will provide the operational framework for moving into the next generation National Airspace System.

With over 600 recommendations now formally developed, there is a recognized need for an assessment of the program's benefits and costs which will evaluate progress to date. This report should be read in conjunction with the *NAR Interim Report* and *NAR Implementation Plan* in order to gain a more detailed understanding of the NAR program and process.

The "Enhancement Area" classification developed for the *NAR Implementation Plan* provides a comprehensive grouping of recommendations and is the basis upon which the benefit and cost identification and quantification is made. Of the twenty enhancement areas identified to date, the Airport Radar Service Area (ARSA), Air Route Traffic Control Center (ARTCC) Resectorization, and Random Routes aspect of the area navigation (RNAV) Integration Enhancement Areas have been evaluated to determine benefit-to-cost ratios.

Each enhancement area is broken down into quantifiable benefits and costs which are then individually evaluated. The results of this step are then aggregated so as to compare benefits and costs for the area as a whole.

AIRPORT RADAR SERVICE AREA (ARSA)

ARSAs are intended to replace Terminal Radar Service Area (TRSA) airspace with a simplified airspace configuration and mandatory communications requirement. The dollar value of cost savings arising from ARSAs is estimated based upon ARSA implementation at all 139 current TRSAs and is expected to be realized until 1992. Benefits are estimated to total $84.5 million in discounted 1983 dollars.

The costs associated with implementing and operating ARSAs are comprised of various types of delay experienced by VFR aircraft and training/educating controllers and pilots. These costs are estimated to total $43.9 million in discounted 1983 dollars. The estimated ARSA benefit-to-cost ratio is thus 1.92 to 1.00.

ARTCC RESECTORIZATION

The ARTCC Resectorization Program was undertaken to streamline and reduce the number of en route sectors in an effort to improve current controller productivity, improve traffic flow efficiency, enhance current automation capabilities, and assist in positioning the air traffic control system for future technological improvements envisioned in the *NAS Plan*.

The primary quantified benefits of resectorization are avoided controller labor costs and attendant avoided equipment costs. These are estimated based on a reduction of 135 sectors and are expected to continue until 1990. Benefits are estimated to total $303 million in discounted 1983 dollars.

The costs of resectorization have already been incurred and are comprised mainly of labor hours for implementation. The total cost is estimated to be $12 million in discounted 1983 dollars.

The benefit-to-cost ratio of the program is estimated to be 25.25 to 1.00, exclusive of intangible benefits to the system arising from the program.

RNAV INTEGRATION: RANDOM ROUTES

RNAV Integration is a broad enhancement area, elements of which are scheduled for implementation as late as 1988. The Random Routes aspect of this enhancement area is evaluated in this report.

The Random Route aspect of RNAV Integration is a set of activities directed toward enhancing pilot use of, and controller ability to accommodate, increased random area navigation in flight.

The primary benefit from undertaking such actions will be reduced fuel consumption. Based on fleet makeup, size, and increasing rate of RNAV utilization, this reduction is estimated to total $1.547 billion in discounted 1983 dollar benefits for the 17-year period to 2000.

Costs include program development, controller and pilot training, and RNAV avionics. Together these costs are estimated to total $676 million in discounted 1983 dollars through 2000.

The estimated benefit-to-cost ratio (low order) for this Enhancement Area is 2.29 to 1.00.

Figure 1 presents a summary of these estimated enhancement area benefits and costs. Note that these three areas combined represent a net cost avoidance/savings of $1,202.6 million.

Future semi-annual updates of this document will evaluate additional enhancement areas leading to an ultimate ratio for the entire program. A tabular summary of the enhancement areas quantified to date is presented in Appendix A.

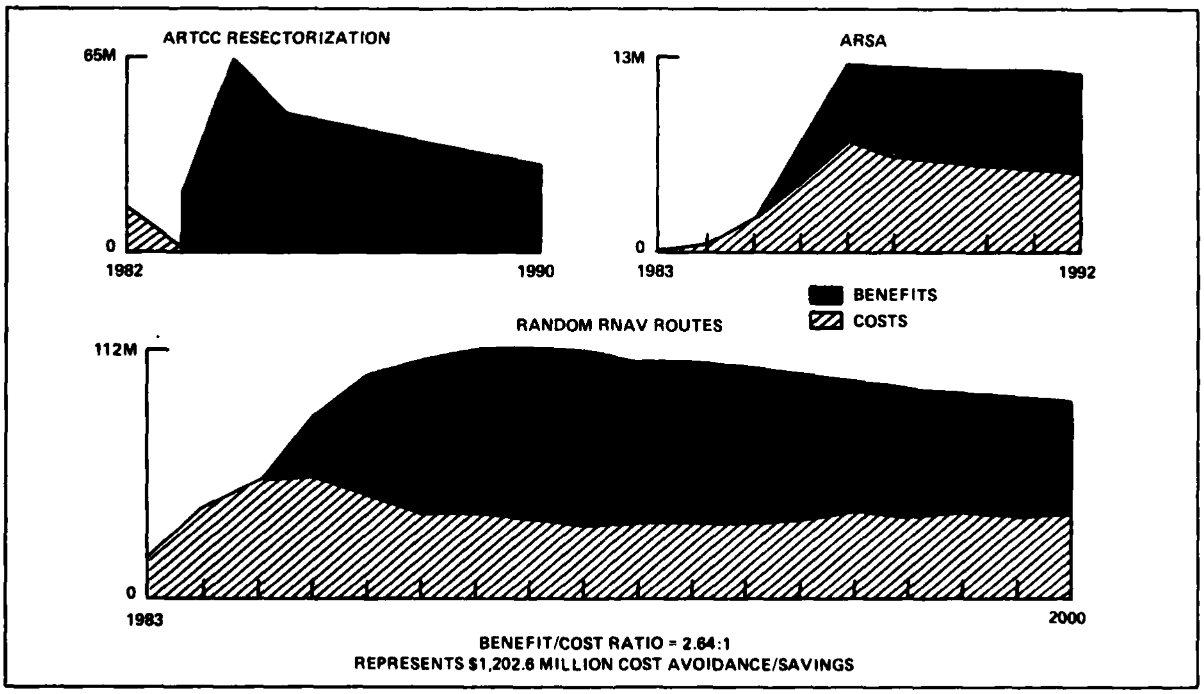

Figure 1. Summary of Quantified Enhancement Area Benefits and Costs

CHAPTER 1
INTRODUCTION

The National Airspace Review (NAR) is a cooperative venture of the aviation industry and government. Using a synergistic approach, the NAR is comprehensively reviewing air traffic control procedures, flight regulations, and airspace for the purpose of validating the current system or identifying near-term changes which will promote greater efficiency. As a component of the *National Airspace System Plan (NAS Plan)* the NAR will provide the operational framework for moving into the next generation National Airspace System.

Since its inception in 1981, the NAR Program has operated with a small staff developing approaches to problem identification, task group meeting organization, special analyses, and implementation of recommendations. With the assistance of Engineering and Economics Research, Inc., the staff has planned and implemented over 40 task group sessions, the membership of which has been comprised of various aviation, military, governmental, and labor organizations. These task groups have generated over 600 recommendations for enhancements to airspace, flight regulations, or procedures. Validation of many aspects of the current system has also taken place. Despite changes to the NAR agenda and adjustments necessitated by some task group recommendations and other special requests, the NAR Program has remained within budget in each year of operation.

The National Airspace Review is directly related to the *NAS Plan*. The *NAS Plan* was developed in response to the "compelling problems of how best to accommodate spiraling demands for aviation services, constrain costs, recast the required technical framework, and deal with aging facilities."[1] In short, the plan was undertaken because expected future system operating costs without the plan were estimated to reach $2 billion per year more than with the plan.[2] Similarly, the NAR has undertaken to provide the near term equivalent of the *NAS Plan*: accommodating user demand and constraining costs through operational and regulatory improvements to the Air Traffic Control (ATC) system. The *NAS Plan* is specifically geared to accommodate NAR task group recommendations[3] and consideration of the *NAS Plan* in NAR task group recommendations has been assured through participation by NAR Program Management Staff (PMS) representatives in task group meetings.

Consistent with the NAR Program objectives, and with over 600 recommendations now formally developed, there is a need for an assessment of the program's benefits and costs, both as to its immediate effects and as the program progresses. As a first step in this assessment process, it is important to categorize recommendations so that groups of recommendations that are interrelated are assessed as a whole and so that a better understanding of the types of benefits and costs that might be realized may be obtained.

A classification approach that has been developed within the *NAR Implementation Plan*[4] is

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[1] U.S. Department of Transportation, Federal Aviation Administration, *National Airspace System Plan*, April 1983, Executive Summary.

[2] *Ibid.*, chart, pg. I-38.

[3] *Ibid.*, Executive Summary.

[4] U.S. Department of Transportation, Federal Aviation Administration, *NAR Implementation Plan*, January, 1983, pg. 1-1. (Hereinafter, *Implementation Plan*)

the System Area/Enhancement Area classification. This approach groups recommendations with a focus on the results of their implementation and also largely parallels the *NAS Plan* organization. Moreover, this classification approach provides a comprehensive overview of the expected outcome of the NAR Program and will be used to guide analysis of the benefits and costs of NAR recommendations. To date, twenty enhancement areas have been developed to fully contain all current NAR recommendations.

This report presents analyses of the Airport Radar Service Area (ARSA) and ARTCC Resectorization Enhancement Areas, as well as an analysis of the Random Routes aspect of the area navigation (RNAV) Integration Enhancement Area. Additional enhancement areas will be analyzed in future updates of this report. Updates are currently scheduled to occur semiannually.

The remaining chapters cover methodological approach (Chapter 2), the ARSA Enhancement Area (Chapter 3), the ARTCC Resectorization Enhancement Area (Chapter 4), and Random Routes within the RNAV Integration Enhancement Area (Chapter 5). The appendices following the report contain the detailed information upon which this benefit-cost analysis relies in part.

This benefit-cost analysis is one of three reports that should be read together. Along with the *NAR Implementation Plan*, this report is built on the foundation laid in the *NAR Interim Report* and should be read in that light. More extensive information on the NAR Program, its structure, process, and implementation timetable may be obtained by reference to these other reports.

CHAPTER 2
ANALYTIC METHODOLOGY

INTRODUCTION

The process of analyzing the benefits and costs of NAR enhancement areas begins with defining what an aviation-related benefit and cost is and then evaluating each enhancement area based on these definitions.

BENEFITS

A NAR enhancement area benefit is one that improves overall system operating efficiency, increases capacity, reduces delay, or increases safety. These types of benefits constitute the broad categories within which the benefits of the NAR Program recommendations are evaluated. They are assisting in the identification of the specific benefits which can be expected to be realized in each NAR enhancement area. Examples of benefits that fall into each of these categories include the following:

- Safety Increases
  - Reduction in midair collisions (MACs)
- Capacity Increases/Delay Reductions
  - VFR separation standards changes in ARSAs allowing reduced VFR delays in ARSAs
- System Efficiency Increases
  - Fuel savings from increased random area navigation (RNAV)
  - Enhanced controller and system effectiveness due to ARTCC sector boundary realignments that more accurately follow major traffic flow patterns

COSTS

Costs associated with the development and implementation of NAR enhancement areas include those arising from operation in the resulting revised ATC environment. These costs have been captured by conceptualizing NAR enhancement area implementation activities in terms of their "life-cycle" effects. It is generally considered that life cycle costs fall into four main categories:[5]

1. Research and Development
2. Investment (Project Start-up)
3. Operations and Maintenance
4. Termination

The NAR Program and its enhancement areas will be evaluated primarily by utilizing the first three of these four areas as the general basis for cost identification. Termination costs are normally only associated with capital- or equipment-intensive undertakings. The NAR is primarily concentrated on non-capital intensive improvements, and thus termination costs are very unlikely to arise. Task group costs, near term project design/initiation costs, and implementation costs borne by FAA are included in the research and development category.

It should be noted that these life-cycle costs are not in all cases fully chargeable to the NAR

[5] U.S. Department of Transportation, Federal Aviation Administration, *Economic Analysis of Investment and Regulatory Decisions—A Guide*, Report No. FAA-APO-82-1, January, 1982, Chapter 4, pg. 4-6.

or to implementation of the recommendations that constitute a particular enhancement area. Many activities, projects, and new initiatives are constantly underway within FAA. Invariably, some actions necessary for one initiative will assist in achievement of another. It is felt that some activities necessary for implementation of NAR recommendations would be undertaken in any event and that, therefore, some of the NAR implementation costs should properly not be charged to the NAR. While not measured here explicitly, such cost considerations are nevertheless important in the final decision-making process.

INTANGIBLE BENEFITS AND COSTS

Intangible benefits and costs arising from improvements to the system should be considered—those for which meaningful dollar estimates cannot be generated. In particular, intangible benefits fall generally into the category of system efficiency improvements. For instance, benefits such as improvements arising from regulatory simplification or elimination are mainly intangible. Elimination or simplification of a part of the Federal Aviation Regulations (FARs) does not usually provide quantifiable time or labor savings but might, nevertheless, ease the burden of study and education required of pilots operating in the NAS. Such benefits should be considered in an overall judgment of a given project or activity.

A variety of intangible benefits are being, and will continue to be, realized as a result of the NAR Program. Because these are not specifically assignable to any particular enhancement area, but rather are associated with the NAR Program generally, they are listed here to be considered as part of each specific NAR project or activity.

- The NAR Program is an effective vehicle for user/provider communication. Through a comprehensive review/analysis of the current system, it affords timely, efficient, and coordinated input to the review plan, task group studies, and proposed action notices, and encourages the identification of problems and responsive near-term system adjustments.

- The NAR Program provides up-to-date documentation through Advance Information Packages, task group minutes and staff studies, and implementation studies.

- The NAR Program enhances effective and integrated communication across functional lines among all FAA entities.

- The NAR Program provides an efficient forum in which concepts and proposals can be considered and tested to estimate their feasibility, potential impacts, and user/provider reaction.

The following benefits arise from planned use of expert contractor support:

- Corporate memory and centralized documentation and data for system adjustments and tailored responses to user/provider inquiries

- Accurate reporting/documentation of system needs and viewpoints of both users and providers

- Objectivity in the conduct of special studies or further analysis and evaluation of recommendations

- Responsiveness and timely accomplishment of tasks

Intangible costs of the NAR are largely limited to the value of those forgone opportunities for application of time and material resources to other projects that have been instead committed to the NAR. Based on a review of major projects or programs currently underway or planned at FAA, resources committed to the NAR are not hampering implementation of any other major project or program.

MEASUREMENT APPROACH

The measurement of benefits and costs directly, especially of items such as efficiency, is not in all cases a straightforward undertaking. For some benefits and costs substitute measures must be found which can more readily be expressed in quantitative terms and aggregated with other, direct benefit and cost measurements to produce overall benefit-to-cost ratios for NAR enhancement areas.

As the first step in this process, the NAR recommendations were grouped into identifiable and homogeneous sets. The System Area/Enhancement Area classification in the *NAR Implementation Plan* has been used for this purpose. This classification contains the Model B/Airport Radar Service Area (ARSA), Air Route Traffic Control Center (ARTCC) Resectorization, and the Random Routes aspect of the RNAV Integration Enhancement Areas treated in this report. Each of these activities is the culmination of a NAR-related activity or set of recommendations. Although this grouping basis provides meaningful sets of recommendations, it should be noted that, in several cases, recommendations have fallen into more than one enhancement area; thus, measurement of costs on an enhancement area basis—rather than on a recommendation-by-recommendation basis—will lead to some overestimation of costs because of the double counting that must occur. The degree to which double counting occurs is not currently considered large and is not highlighted in this report.

The next step in the evaluation of benefits and costs is the identification and listing of the effects of each identifiable project that may evolve out of each enhancement area. This process of identification proceeds at the same time as units of measurement are identified. The exact definition of effects depends upon the chosen measurement unit and *vice versa*. This process of repeating steps is continued until a satisfactory and complete representation of benefits and costs is achieved for each enhancement area. For instance, though Model B/ARSA airspace might contribute significantly to increased user satisfaction (for those currently using Terminal Radar Service Areas (TRSAs)), user 'satisfaction' might best be measured in terms of reduced delays in traversing such areas, better information on traffic (reduced hazards or reduced separation requirements), and other quantifiable concepts rather than 'satisfaction'.

An additional determination required at this stage is that of the appropriate time period over which benefit and cost streams should be assessed. This depends in part on the *NAR Implementation Plan*,[6] and the anticipated timing-related system improvements identified in the *NAS Plan*, both of which provide indicators of appropriate enhancement area implementation timing.

Once effects are identified, classified as benefits or costs, and have dollar estimates assigned to them, aggregation of benefits and costs by Enhancement Area by year proceeds. Once this aggregation is done, a discount factor is applied to each year's benefits and costs (assuming 1983 as the current year) based on the Office of Management and Budget, OMB Circular A-94, suggested ten percent per year discount rate.

Following application of discount factors, the total present value of benefits and costs for each enhancement area is determined and is used to generate a benefit-cost ratio for that enhancement area. Figure 2 provides a schematic diagram of the process used to develop these measures and perform the analysis.

This analytic methodology is applied in this report by developing quantitative scenarios, and estimates of the benefits and costs, for ARSA implementation, ARTCC Resectorization, and the Random Routes aspect of RNAV Integration.

TASK GROUP MEETINGS

As a preliminary matter, each enhancement area involves, as a cost, the occurrence of task group

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[6] *Op. cit., Implementation Plan*. See timing charts for each Enhancement Area.

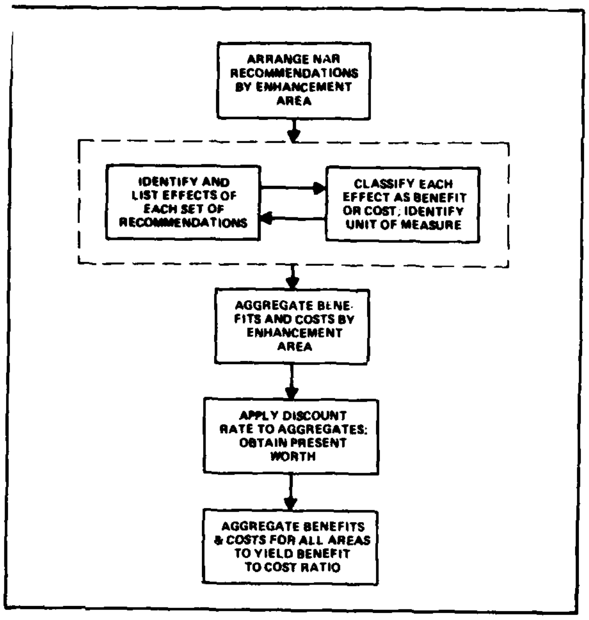


Figure 2. General Methodological Approach to Analysis of NAR Benefits and Costs

meetings. ARTCC Resectorization does not include these costs because its costs were incurred prior to the advent of the NAR task group meetings. Because the costs of those meetings will generally be a relatively small percentage of overall enhancement area costs, a representative average has been developed for the costs of a single task group meeting. These costs, shown in Figure 3, incorporate estimates of the labor and travel expenses for each category of organization and cover the entire task group meeting process from initial planning through staff study, including briefings, presentations and disposition of recommendations that may be associated with the meeting's subject matter. In addition, overhead costs, not specifically chargeable to task group meetings are included in this overall average costs of task group meetings.

FAA costs incorporate labor and travel associated with pre-meeting materials preparation, conferences with prospective task group chairmen and technical support personnel, actual task group meeting activities, and a variety of post-meeting documentation.

National Airspace Review Advisory Committee (NARAC) member costs include estimates of pre-meeting reviews of Advance Information Packages (AIPs), other preparation for task group meetings, participation during meetings, correspondence with associated membership following meetings, and review of post-meeting reports.

Technical support provided by Engineering and Economics Research, Inc., includes preparation of all materials used before and during task group meetings, preparation of daily summary minutes, preparation of all staff studies, and other post-meeting technical support which includes classifying recommendations, review and correction of staff studies, entry of new recommendations into the automated tracking system and oversight of enhancement areas implementation.

Related NAR Staff activities includes all costs that are overhead to task group meetings including travel, briefings, and presentations supporting the NAR Program and process generally.

FAA	$21,500
NARAC MEMBERS	21,500
TECHNICAL SUPPORT	45,300
RELATED NAR STAFF ACTIVITIES	6,000
TOTAL	$94,300

FIGURE 3. NAR PROGRAM AND TASK GROUP MEETING COSTS (1983 DOLLARS)*

*SEE APPENDIX FOR DETAILS

Figure 3. NAR Program and Task Group Meeting Costs (1983 Dollars)

Where the recommendations for a given enhancement area indicate that several task group meetings have contributed to the evolution of that area, a judgment has been made as to the aggregate number of task group meetings associated with each. In addition, this approach allows greater facility in charging partial task group meeting costs to one or more enhancement areas.

CHAPTER 3
AIRPORT RADAR SERVICE AREA (ARSA)

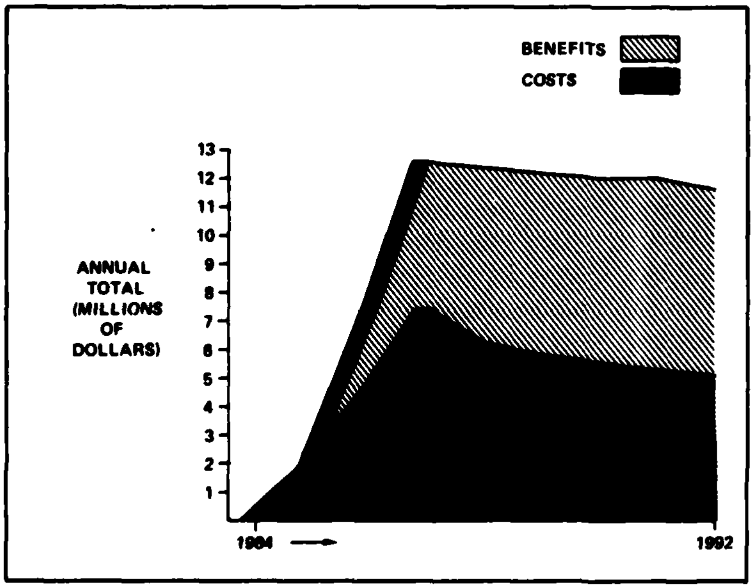
SUMMARY

The ARSA concept involves restructuring the airspace around some airports currently designated as Terminal Radar Service Areas (TRSAs). The concept, developed during NAR Task Group 1-2.2, is now undergoing operational confirmation at two sites (Columbus, Ohio, and Austin, Texas).

The scenario used here assumes that the ARSA concept will be applied, over time, to 139 current TRSA sites and that its effects will last until 1992. Benefits examined include a reduction in mid-air collisions (MACs) and a reduction in delays experienced by VFR aircraft, during off-peak hours, due to the reduced separation minimums in ARSA airspace versus that in TRSAs. Costs include delay increases experienced by VFR aircraft in entering ARSA airspace (due to the new two-way radio communications requirement), those experienced by all aircraft (during peak hours) due to arrival sequencing, and those experienced by VFR aircraft prior to departure as a result of the ARSA departure clearance requirement.

Total estimated benefits and costs are presented in Figure 4, both on an annual basis and in the aggregate. The ARSA benefit-cost ratio is estimated to be 1.92 to 1.00 based on these assumptions.

An intangible benefit arising from the ARSA concept is the clarification of pilot and controller responsibilities and, probably, easing of pilot education (especially among student pilots) due to the simplicity of the concept.



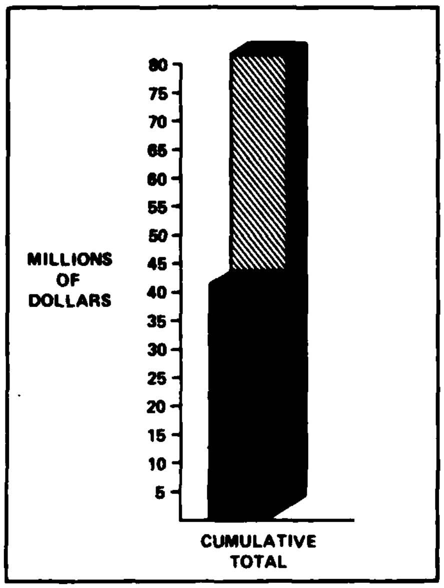


Figure 4. Summary of Annual and Overall ARSA Benefits and Costs (Discounted 1983 Dollars)

INTRODUCTION

Implementation of the ARSA concept involves the restructuring of airspace around many airports currently designated as Terminal Radar Service Areas (TRSAs). Instead of the current TRSA voluntary participation, aircraft will be required to maintain two-way radio contact with ATC while within the ARSA core area (within five nautical miles of the airport tower, from the surface to 4000 feet height above airport (HAA), and from five to ten nautical miles out while between 1200 and 4000 feet HAA). All aircraft operators arriving at an ARSA airport are required to participate in arrival sequencing, but VFR separation minimums are reduced within the airspace core. All aircraft departing from ARSA airports are required to obtain a departure clearance.

The ARSA concept was primarily developed during NAR Task Group 1-2.2 and is currently undergoing an operational confirmation at two sites (Columbus, Ohio, and Austin, Texas) prior to expanded application. In support of this operational confirmation, the Office of Aviation Policy and Plans (APO) has prepared an economic analysis for the two sites involved.[7] The benefit-cost analysis presented here is based on a modified extrapolation of this APO work.

The APO study identified the principal benefits from ARSAs as being a reduction in midair collisions (MACs) and a decreased VFR separation standard which will lead to reduced VFR delays in non-peak hour arrivals. The study identified the principal costs as including training and education, departure delays for currently non-participating VFR aircraft, peak hour arrival sequencing delays, and delays due to the ARSA mandatory communications requirement. The primary source measures for the APO study were controller interviews (for delay estimates) at the operational confirmation sites and an APO-developed regression analysis linking ARSA-avertable MACs to traffic levels at TRSA sites.

The delay measures used in the APO study have been weighted and applied to all ARSA candidate sites in this study, and the regression analysis relationship has been applied directly to projected traffic volumes at all ARSA candidates to yield aggregated benefits and costs.

Following performance and evaluation of the ARSA concept at Columbus, Ohio, and Austin, Texas, it is assumed that FAA will proceed to implement ARSAs at all existing TRSAs. For purposes of scenario definition, this study assumes that 28 will be implemented in 1985, 45 more in 1986, and a final 64 in 1987. Overall, it is assumed that 139 ARSAs will be in operation by mid-1987, and that their operational effects will be largely expended by 1992. This limitation to 1992 is based on the expectation that other activities, improvements, and airspace or procedural changes will occur between now and 1992 due to other NAR recommendations and *NAS Plan* implementation. These actions are expected to substantially improve aircraft tracking and collision avoidance capabilities. As a result, it is felt that no ARSA-dependent benefits will be distinguishable after 1992. The benefit and cost stream is therefore stopped in 1992 and a benefit to cost ratio determined for that date.

BENEFITS

As indicated in the APO study, the primary, measurable benefits from implementing ARSAs are expected to be a reduction in mid-air collisions (MACs) and an operating cost savings from reduced separation minimums.

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[7] U.S. Department of Transportation, Federal Aviation Administration, *Regulatory Evaluation of Notice of Proposed Rulemaking to Implement an Airport Radar Service Area at Columbus, Ohio, and Austin, Texas*, Office of Aviation Policy and Plans, Regulatory Analysis Branch, July 13, 1983. (Hereinafter *Regulatory Analysis*).

Avertable MACs

The APO study (hereinafter "regulatory analysis") provides the following description of its assessment of ARSA-avertable MACs.[8]

"The FAA conducted an extensive review of MAC accidents that occurred during the period from 1978 to 1982. Data were derived from National Transportation Safety Board (NTSB) accident reports and the FAA Accident/Incident Data System. The FAA considered only those MAC accidents which occurred within proposed ARSA airspace at the 136 airports (as of July, 1983) which employ TRSA services and in which at least one operator was not communicating with ATC or the midair occurred because one operator did not receive arrival sequencing." The FAA projected the number of MACs that would have occurred in the proposed ARSA airspace over the five-year period.

"A regression analysis was developed which provides an analytic expression of the average midair collisions in proposed ARSA airspace per airport providing TRSA services from 1978 to 1982, as a function of average aircraft operations per airport, on the basis of calendar year 1982 operations . . . The five year collision estimator is in the form $C = an^b$ where:

- 'C' is the average number of MACs occurring in proposed ARSA airspace per TRSA airport over the period of January, 1978, to December, 1982;
- 'a' and 'b' are the coefficients which yielded the least error between the actual and estimated number of collisions;
- 'n' is the average number of aircraft operations per TRSA airport in 1982 in units of 100,000 had the ARSA been implemented (local, itinerant, plus an additional average estimate of 10% of local and itinerant to account for additional operations handled by ATC in an ARSA)." Figure 5 provides a depiction of average operations per ARSA assumed for the analysis presented in this report. This average appears to drop after 1984 and then rise in later years because the first year average is based on Austin and Columbus and both have well above average annual operations. The inclusion of more candidate sites in later years lowers the average which then rises consistent with the five percent traffic growth assumed for this analysis.

"When scaled to an *annual* basis by a scaling factor of 4.5 to account for activity growth over the five year period, the ARSA collision formula becomes:

$$C = \frac{0.12\,n^{1.80}}{4.5} = .027n^{1.80}$$

* * *

The costs of a MAC include damage to the aircraft, the value of lives lost and the cost of injuries. The average weighted cost per general aviation MAC accident in 1983 dollars is $1,644,000."[9] This dollar amount is derived by considering such factors as different types of GA aircraft, average numbers of occupants that fly on these aircraft, probabilities that relevant costs will be incurred, and distribution of hours flown by aircraft type.

Utilizing the equation developed by APO, 1982 air traffic activity at TRSAs,[10] and the assumption of an annual five percent increase in traffic

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[8] *Op. cit., Regulatory Analysis*, pp. 8-11.

[9] *Op. cit., Regulatory Analysis*, pg. 26, Table 2.

[10] See U.S. Department of Transportation, Federal Aviation Administration, *Airmens Information Manual*, Paragraph 166, December 12, 1982, pg. C4-S1-11, and U.S. Department of Transportation, Federal Aviation Administration, *FAA Air Traffic Activity, September, 1982*, pp. 16-45.

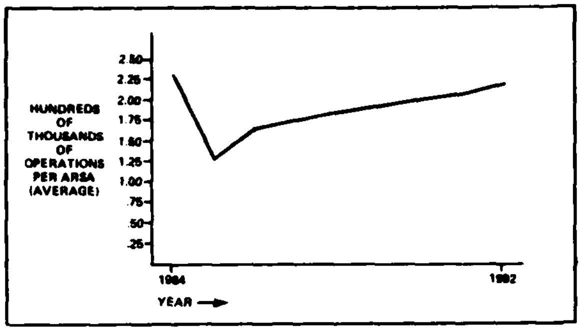

Figure 5. Average Operations Per ARSA by Year

activity at potential[11] ARSA sites, an average value for avertable MACs per ARSA site per year was developed. The discrepancy between the 4.5 percent traffic growth factor used to estimate ARSA-related MAC reductions and the five percent used for future activity growth arises from the fact that the actual growth trend at the surveyed potential ARSA sites was 4.5 percent for 1978-1982 whereas the five percent future growth factor is a projection. Based on this analysis and the scenario described above, the total MAC reduction anticipated from an ARSA program is 83. Figure 6 depicts the cumulative total of averted MACs projected for the ARSA program on a year by year basis.

Utilizing the annual MAC reduction figures and the APO-developed MAC cost of $1,664,000,

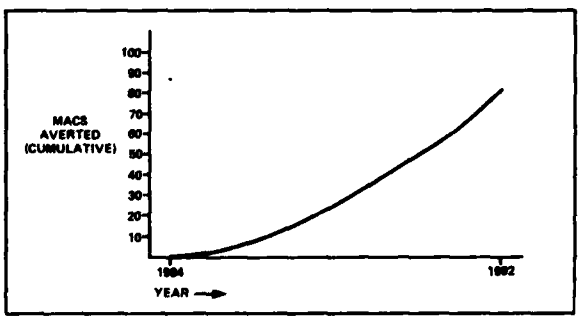

Figure 6. Cumulative Reduction in MACs at ARSAs

MAC reduction-related dollar benefits have been derived. These benefits are displayed in Figure 7.

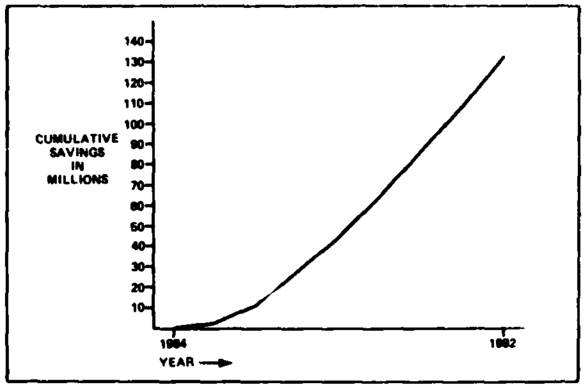

Figure 7. Cumulative Dollar Savings from MAC Reduction (Undiscounted)

Reduced VFR Separation Minima

The regulatory analysis described benefits from reduced VFR separation minima as follows:[12]

"Certain VFR operators should experience some savings in arrival time as a result of the proposed reduced separation minimums (1 1/2 miles to approximately 400 ft. horizontally)." Based on estimates by local ATC personnel at the two operational confirmation sites, this proposed rule would, using a straight-line average,[13] save 60 operators one minute per operation, per day, three days per week. If this estimate is applied at each ARSA site, then 9360 flights per year per ARSA site would benefit by one minute of reduced delay. Because the program begins with only two sites and then increases to 30, then 75, and finally 139, the delay reduction benefit appears to decrease

[11] *Op. cit., Regulatory Analysis*, pp. 11-12.

[12] *Ibid.*

[13] Estimates at the two sites differ slightly. For purposes of this analysis, a straight-line average is applied for all potential ARSA sites.

dramatically in the first few years and then flatten out in later years. Later year increases in the benefit arise from increased traffic activity alone. This is shown in Figure 8.

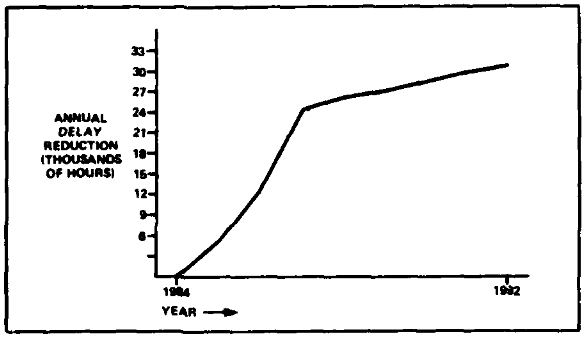

Figure 8. Reduced Delay in ARSAs (Due to Reduced VFR Separation Minimums)

APO estimates that the average variable operating cost (VOC) (private pilot/crew time, fuel and oil, and maintenance) of a general aviation (GA) aircraft is $89.94 per hour.[14] Based on this figure, total hours saved, and the five percent traffic increase already noted, total VFR separation reduction savings were developed and are depicted in Figure 9.

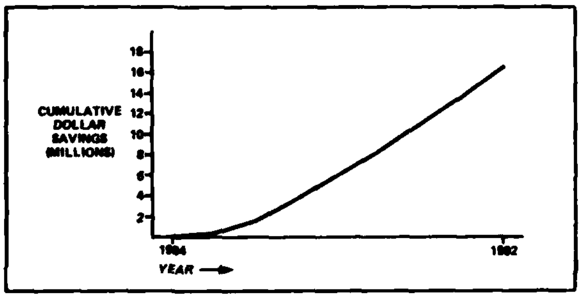

Figure 9. Cost Savings from Reduced Delays in ARSAs (Undiscounted)

[14] *Ibid*. And see U.S. Department of Transportation, Federal Aviation Administration, *Economic Values For Evaluation of Federal Aviation Administration Investment and Regulatory Programs*, Report No. FAA-APO-81-3, September, 1981.

Total ARSA Program benefits were derived by combining the two cost savings just described. This total was then discounted in conformance with OMB Circular A-94 to yield a present worth in 1983 dollars. Based on this methodology, the total discounted value of ARSA program cost savings is $84.5 million. This is depicted in Figure 10.

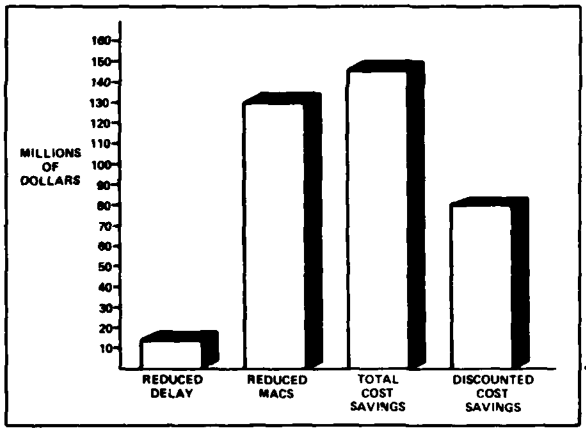

Figure 10. Total Discounted ARSA Benefits (1983 Dollars)

COSTS

The costs associated with implementation and operation of ARSAs fall primarily into five categories.

- Costs incurred in development of the NAR Program, and in particular, arrangement and convening of Task Group 1-2.2, which developed the ARSA concept and parts of other task group sessions that made limited inputs to the concept.
- VFR departure delays expected to affect certain types of general aviation operators not currently participating in TRSAs.
- VFR arrival sequencing delays occurring during peak hours as a result of ARSA mandatory sequencing requirements.

- VFR delays occurring as a result of the requirement for ATC permission to enter an ARSA.

- Federal government costs associated with the initial operational confirmation and training/education at each ARSA site.

Each of these cost elements is detailed below and in the accompanying figures. Total discounted costs for the ARSA Program are estimated to be $43.9 million.

The APO study describes the following costs.[15]

Task Group Meetings

In addition to the entire session of Task Group 1-2.2, one-half of the sessions of Task Groups 1-2.3 and 1-2.4 concentrated on issues associated with this concept. As a result the total task group meeting related costs of the ARSA concept are $188,658.

VFR Departure Delay

"On the basis of previously provided Stage III TRSA services, it has been estimated by air traffic controllers that 33 percent of operators departing VFR would not participate in the full ARSA departure services if voluntary.[16] FAR Part 91.87 already requires that operators departing an airport traffic area maintain two-way communication with ATC. The new additional requirement imposed by the ARSA is that these VFR operators would be required to contact clearance delivery for a departure frequency and departure code. The time for an operator to contact clearance delivery is estimated to be 1 minute. This would not impact IFR operators because they are already required to contact clearance delivery." It is estimated by local ATC personnel at the two operational confirmation sites that, based on a straight line average,[17] 66 VFR departures per day (33 percent of 200 daily VFR departures), per ARSA will experience this one minute delay. Figure 11 displays the hours of delay that will be experienced due to departure clearance requirements as well as for arrival sequencing and ARSA entry requirements. The delays shown are both cumulative and additive, with each type of delay represented by the space between the lines bounding its label.

"FAA assumes that these are mostly general aviation operators and, on the basis of local ATC personnel estimates, that the mix of aircraft flown by these operators is 50% - 30% - 20% for single engine piston (SEP), multi-engine piston (MEP) and turboprop (TP), respectively. Furthermore, FAA estimates the value of time to operators of SEP, MEP and TP aircraft in 1983 dollars is $21.56, $40.66 and $179.82 per hour, respectively. These estimates are based on the assumption that operators of SEP aircraft are private pilots, while operators of MEP and TP aircraft are salaried crew pilots. FAA believes that assuming the pilots of MEP and TP aircraft are salaried crewmembers overstates the actual cost impact. On the basis of these values of time cost factors and mix of aircraft flown by these operators, the average weighted GA operator value of time per hour is $58.95."[18] Figure 12 presents an overall estimate of cumulative delay costs based on total hours and operator value per hour.

VFR Arrival Sequencing Delay/Peak Hours

"Certain VFR operators could experience some delay during ATC peak hour operations resulting from mandatory arrival sequencing requirements. While these operators would benefit

[15] *Op. cit., Regulatory Analysis*, pp. 15-21.

[16] Thirty-three percent is an average of the figures for Austin and Columbus.

[17] See footnote 13.

[18] *Op. cit., Regulatory Analysis.*

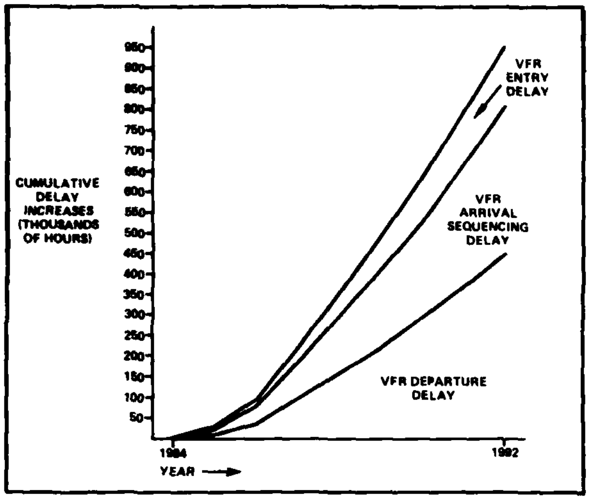

Figure 11. Cumulative Delay Increases Due to ARSAs

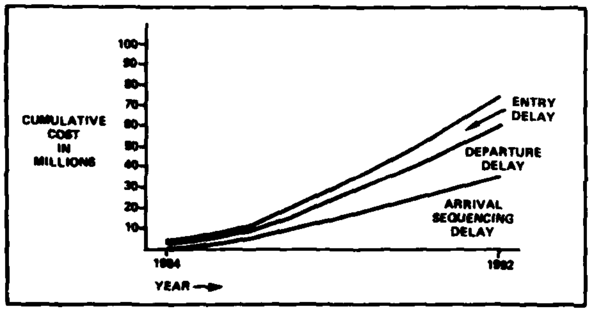

Figure 12. Cumulative Cost of ARSA Delay Increases (Undiscounted)

from ARSA reduced separation minimums with time savings of approximately one minute, they would experience delays of approximately 2.5 minutes or a marginal arrival sequencing delay of 1.5 minutes per operation." This requirement, based on estimates by local ATC personnel at the two operational confirmation sites, would on the average[19] impact 60 operations per day, four days per week.[20] Figures 11 and 12 (above) provide a summary of these delays and costs.

VFR Delay Encountered to Enter the ARSA

"Certain VFR operators could experience some delay as a result of being denied immediate entrance into the ARSA when ATC handling of arriving traffic is at capacity." Estimates by local ATC personnel at the two operational confirmation sites indicate that, on the average,[21] 50 operations per week will experience an average three minute delay before they are given ATC approval to enter an ARSA.[22] These delays and costs are also shown in Figures 11 and 12.

FAA Education, Training Program and Administration Costs

The FAA has undertaken an operational confirmation of the ARSA concept at two sites. Costs for supporting this activity in the form of study design, data collection, and evaluation are expected to total approximately $500,000.

In addition, the FAA will incur initial one-time only costs to train local FAA facility managers' staffs and conduct meetings with local airmen to explain the ARSA concept. The initial nonrecurring costs relating to this requirement include personnel costs, travel, per diem, town hall rental, letters to airmen, bulletins, etc., and are approximately $20,000.[23] Overall costs for this training and education activity are presented in Figure 13.

A summary of ARSA Program costs is presented in Figure 14.

Overall, implementation of the ARSA concept would generate an estimated $84.5 million in benefits and $43.9 million in costs through 1992. Based on these estimates, the benefit-to-cost ratio for the ARSA program is estimated to be 1.92 to 1.00 and is depicted in Figure 15.

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[19] See footnote 13.

[20] *Op. cit., Regulatory Analysis.*

[21] See footnote 13.

[22] *Op. cit., Regulatory Analysis.*.

[23] *Op. cit., Regulatory Analysis*, pg. 20.

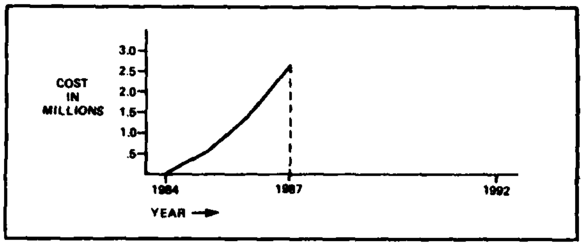


Figure 13. Cumulative Costs of Training and Education (Undiscounted)

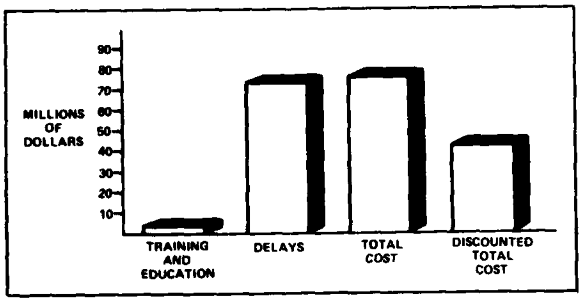


Figure 14. Total Discounted ARSA Costs (1983 Dollars)

INTANGIBLES

An intangible benefit arising from the ARSA concept is the clarification of pilot and controller responsibilities and, probably, easing of pilot education (especially among student pilots) due to the simplicity of the concept.

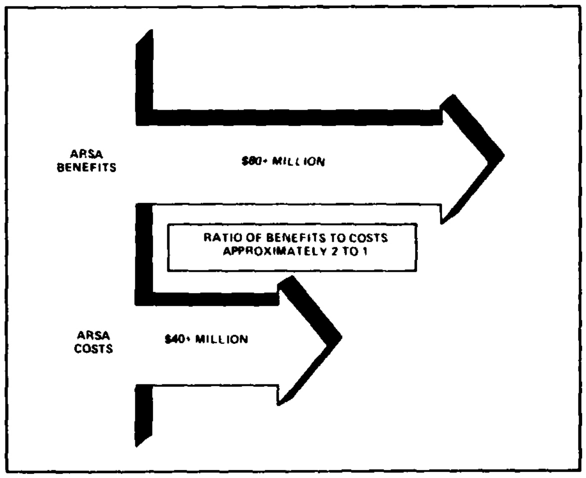


Figure 15. Benefit-Cost Ratio of ARSA Enhancement Area

CHAPTER 4

ARTCC RESECTORIZATION

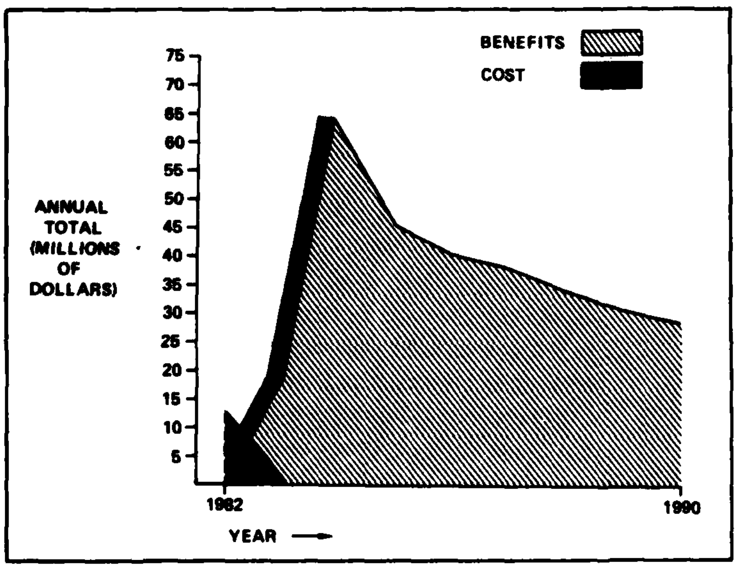
SUMMARY

Among the earliest planned activities of the NAR was an examination of a program to re-align ARTCC sector boundaries to more closely reflect traffic flows, eliminate or reduce conflicts, enhance current automation capabilities, level controller workload, and improve system capacity. This Resectorization Program began prior to the NAR, however, due to the controllers' strike. Its implementation is now virtually complete.

Quantifiable benefits from the program are primarily labor savings arising from a reduction from 721 to 586 sectors (135 sectors eliminated). The sector reduction translates into $55 million per year in avoided controller salaries. This labor savings can be considered an annual savings as long as other events do not occur which would reduce required controller numbers regardless of resectorization. A general reduction in required controllers cannot be expected before some form of the Automated En Route ATC (AERA) concept is implemented. This is not expected before 1990. In addition, a one-time equipment cost avoidance of $70 million is anticipated.

Primary quantifiable costs for the program include program development, labor hours for implementation, travel, and equipment. Most of these costs have already been incurred and total approximately $12 million.

The estimated benefits and costs of the Resectorization Program are displayed in Figure 16. The anticipated benefit-cost ratio of the program is estimated to be 25.25 to 1.00.



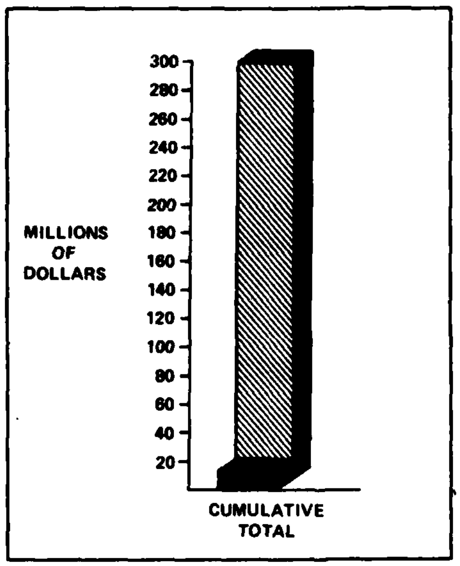


Figure 16. Summary of ARTCC Resectorization Benefits and Costs by Year and Overall (Discounted 1983 Dollars)

Intangible benefits from resectorization include:

- an increase in overall system effectiveness arising from sector boundary realignments that follow major traffic flows more closely;
- laying groundwork for increased random area navigation operations in the NAS;
- an improvement in the balance of work placed on different versions of the NAS 9020 computers which is enhancing the working life of the overall computer system;
- more efficient metered traffic flows in terminal areas;
- encouragement of en route metering through realignments that recognize an approximate 200 nautical mile radius around major airports;
- encouragement of more fuel efficient descents through realignments that recognize an approximate 135 nautical mile radius around major airports; and
- increased en route safety and efficiency due to removal of sector boundaries from existing traffic conflict points.

INTRODUCTION

One of the initial objectives of the National Airspace Review was an examination of a program to realign ARTCC sector boundaries to more closely reflect traffic flows, eliminate or reduce conflicts, enhance current automation capabilities, level controller workload from sector-to-sector, and improve system capacity.

While the resectorization program was intended to be the subject of the first task group meetings, its implementation was forced to begin prior to the NAR program due to the severe shortage of controllers caused by the 1981 strike. Implementation of the resectorization program thus began in mid-1982 and is now virtually complete. To date, all of the program's sector reduction and workload objectives have been met. One-hundred thirty-five sectors (out of more than 720 originally) have been eliminated. This has in turn allowed for the retirement of much of the expensive equipment (Plan View Displays [PVDs]) needed to support controller activities in each eliminated sector. There has been a major equipment cost avoidance even though each ARTCC has retained up to 10 extra sectors as reserves, and sector boundaries have been realigned to accommodate a 30 percent traffic growth factor.

Most of the Resectorization Program's costs have already been incurred. Its benefits, however, can be expected to continue for several more years until some form of the Automated En Route ATC program matures and is implemented. Assuming that this will occur in the early 1990's, the Resectorization Program is assumed to cease to produce benefits and incur costs in 1990.

BENEFITS

The primary quantifiable benefits of the ARTCC Resectorization Program are costs avoided in the form of reduced labor requirements (fewer controllers) and reduced equipment (fewer PVDs).[24] Thus, for each of the 135 eliminated sectors, the need for an average of 11.7 controllers, at $35,000 per year, is eliminated. This totals $55,282,500 per year. Based on the assumption that these labor costs would continue to be incurred in the future unless the Resectorization Program had been implemented, they are assumed to be avoided annually until program termination in 1990.

[24] U.S. Department of Transportation, Federal Aviation Administration, Air Traffic Service, AAT-300, memorandum summarizing estimated benefits and costs of Resectorization Program; May 27, 1982. (Hereinafter "AAT-300 memo".)

In addition, for each of the 135 sectors eliminated, one PVD has been assumed to be eliminated. Eliminated spares are ignored in this analysis because of the additional sectors each center has retained. Thus, 135 PVDs, at $152,200 per PVD, are eliminated for a total equipment cost avoidance of $89,650,125 (approximately $70 million when discounted). Because the program has been phased in during the past year, however, and will not fully realize this avoided cost immediately, only 25 percent of these avoided equipment costs are assigned to 1983, with the remaining 75 percent assigned to 1984. These costs have not been spread over the life of the program because, prior to resectorization, there was a recognized need to replace many of these units. Thus, avoided costs occur earlier in the program than they otherwise might.

Total discounted benefits are thus estimated to be $303 million. These benefits are illustrated in Figure 17.

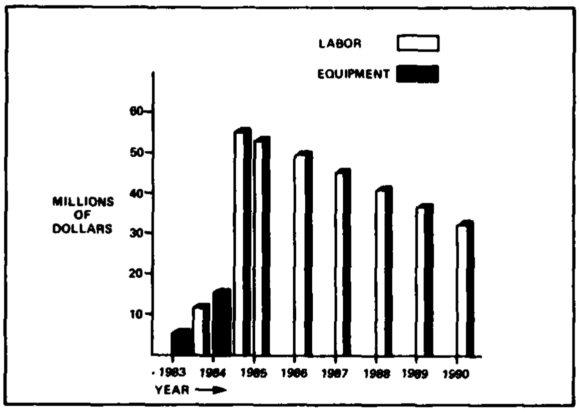


Figure 17. Total Discounted ARTCC Resectorization Benefits by Year (1983 Dollars)

COSTS

The primary costs[25] associated with this program are one-time-only and cover the sector redesign, briefings, multi-level reviews and implementation aspects of the program. Program development, sector redesign, and national and regional briefings and reviews were estimated by Headquarters and regional ATC personnel to total 1,103 man-days. Implementation was further estimated, by the lead Resectorization Program ARTCC, to require from 44,000 to 66,000 man-days total. This wide variation is due to unpredictable differences in implementation workload from ARTCC to ARTCC. Total travel, funded through the NAR budget, was estimated at $74,000. Equipment costs were estimated on a 1983 and 1984 basis at 25 percent/75 percent, similar to the treatment of benefits. Preparation of new video maps was estimated at $500 per ARTCC and sector relocation or reallocation at $8,000 per sector for each of the 135 sectors.

Total discounted costs are thus estimated to be from $10.3 million to $14.1 million with an average of about $12 million. These costs are illustrated in Figure 18.

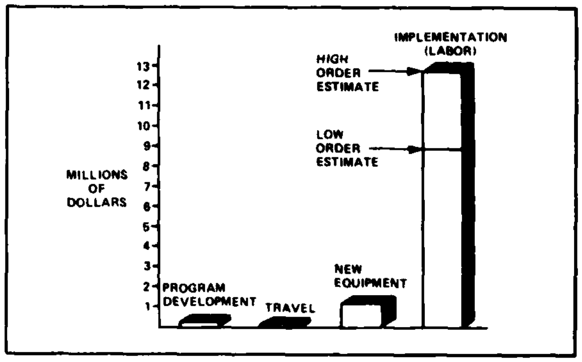


Figure 18. Total Discounted ARTCC Resectorization Costs (1983 Dollars)

The benefit-to-cost ratio for ARTCC Resectorization is estimated to be 25.25 to 1.00, assuming actual costs fall in the mid-range of estimates (i.e., $12 million). This ratio is illustrated in Figure 19.

[25] *Ibid.*

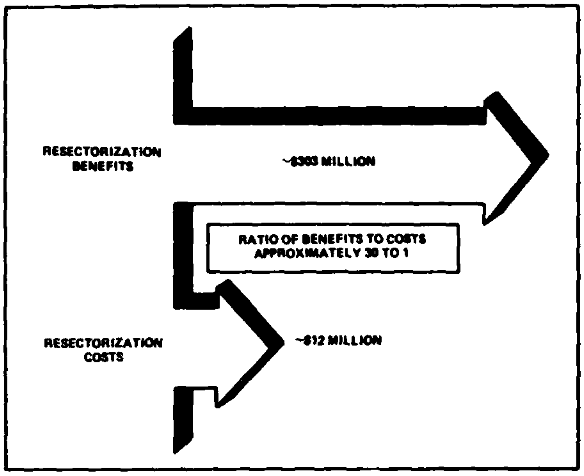


Figure 19. Benefit-Cost Ratio of ARTCC Resectorization Enhancement Area

INTANGIBLES

The Resectorization Program was designed to work at more than one level and to respond to several, sometimes conflicting system requirements. In particular, overall system effectiveness is expected to increase as a result of sector boundary realignments that more accurately reflect major traffic flows. Further intangible benefits are expected from an improved balance of computer workload assigned to different versions of the NAS 9020 computers. This should result in enhancing the useful life of the computer system. In addition to these immediate improvements, resectorization is intended to begin preparing the entire airspace system for the advent of increased area navigation (RNAV) operations. By reconceiving of the system with the presence of RNAV, en route metering, and other advanced automation, sectors were designed to recognize both an approximate 200 nautical mile and 135 nautical mile radius around major airports and were aligned to allow more efficient metered flows. Although runways constitute the ultimate limit on airport capacity, these design objectives have enhanced existing capacity to some degree.

The benefits anticipated from this program may go far beyond mere productivity gains, even though they may not be fully realized for several more years. The immediate analysis has concentrated on the more tangible, near term productivity gains.

CHAPTER 5
RNAV INTEGRATION: RANDOM ROUTES

SUMMARY

The Random Routes aspect of RNAV Integration is comprised of a set of activities directed toward enhancing pilot use of, and controller ability to accommodate, increased random area navigation in flight.

The primary benefit from undertaking such actions will be reduced fuel consumption. Based on fleet make-up, size, and an increasing rate of RNAV utilization, this reduction is estimated to total $1.547 billion in discounted 1983 dollar benefits for the 17-year period to 2000.

Costs include program development, controller and pilot training, and RNAV avionics. Together these costs are estimated to total $676 million in discounted 1983 dollars through 2000.

Figure 20 presents both annual and cumulative totals for RNAV Integration.

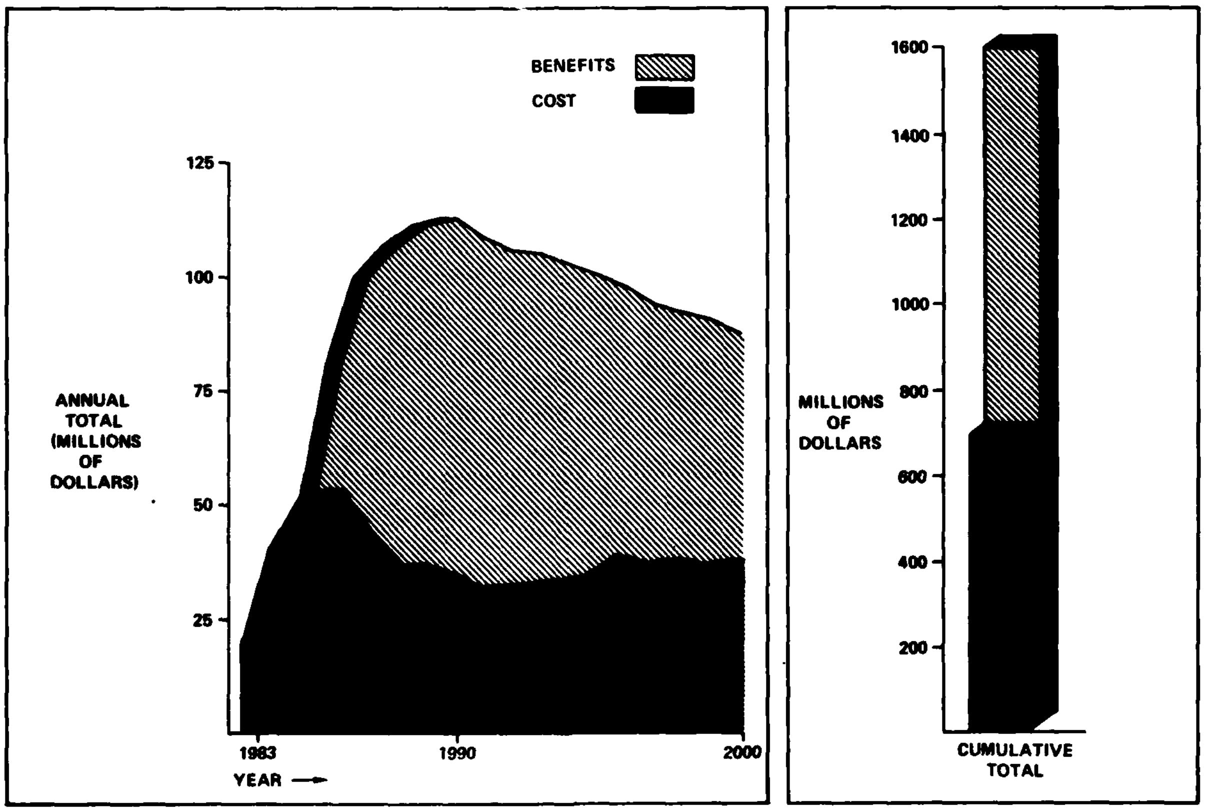


Figure 20. Summary of RNAV Integration Benefits and Costs by Year and Overall (Discounted 1983 Dollars)

The estimated benefit-cost ratio (low order) for this aspect of the Enhancement Area is 2.29 to 1.00.

Intangible benefits of RNAV Integration include an eventual reduction in airway and route inspection/maintenance due to reduced airways and routes in the NAS, and increased pilot positional awareness.

Intangible costs may include some additional effort by pilots, especially students, in order to utilize an airspace system which permits a choice among substantially different navigational methods.

INTRODUCTION

The random routes aspect of the RNAV Integration Enhancement Area is concerned generally with those actions which will lead to the expanded use by pilots of (and ATC capability to accommodate) random area navigation (RNAV) routings. The benefits of undertaking such actions were indicated in Operation Free Flight[26] and are primarily fuel consumption reductions. Costs, on the other hand, will encompass NAR recommendation formulation, program development, controller and pilot training, and RNAV avionics costs. Because no significant alternative to or burden on RNAV use is anticipated in the forseeable future, and *NAS Plan* navigation projections continue only to the year 2000,[27] the benefit and cost stream is taken to that year, beyond which no forecast is currently considered reasonable.

BENEFITS

Operation Free Flight suggested that fuel consumption reductions of 2-3 percent could be expected from random RNAV route utilization in the NAS.[28] Because the VOR/DME navigation system is to be maintained, thus assuring a mixed RNAV and VOR/DME operation of the NAS, a forecast of the future RNAV-equipped fleet and operational utilization of RNAV is required in order to estimate fuel consumption benefits. Figures 21 and 22, showing RNAV avionics equippage and utilization,[29] were developed[30] to estimate these benefits. These projections take into account two anticipated factors. Firstly, with the advent of the operational Global Positioning System (GPS) in 1988, there will be a new incentive for aircraft owners to acquire RNAV avionics, especially if equippage costs are reasonable. Furthermore, it is assumed that RNAV avionics standards will be fully developed and optimized for ATC system integration in the early 1990's (1993) and that this will provide an additional incentive.[31] These two events are represented by discontinuities in the figures. In addition, there are two values for (GA) equippage and utilization. These divergent values are presented because of the lack of a clear indication regarding the degree to which GA owners/operators will move to RNAV despite the fact that recent manufacturing trends seem to be placing more emphasis on lower cost RNAV avionics. (It can be assumed that, as costs for equipment drop relative to any inconvenience arising from not having such equipment, equippage and utilization will increase.)

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[26] U.S. Department of Transportation, Federal Aviation Administration, Air Traffic Procedures Division, *Operation Free Flight*, Final Report, Report No. FAA-AT-81-1, July 1, 1981.

[27] U.S. Department of Defense and Department of Transportation, *Federal Radionavigation Plan*, Vol. 1, "Radionavigation Plans and Policy," Report No. DOD-4650.4-P-1 and DOT-T3C-RSPA-81-12-1, March 1982, pp. I-24 to I-54.

[28] *Op. cit., Operation Free Flight*, pg. I-3.

[29] Number of RNAV hours flown divided by total operating hours.

[30] Estimates are based on Headquarters ATC personnel judgment of implementation effects.

[31] Headquarters navaids personnel judgment.

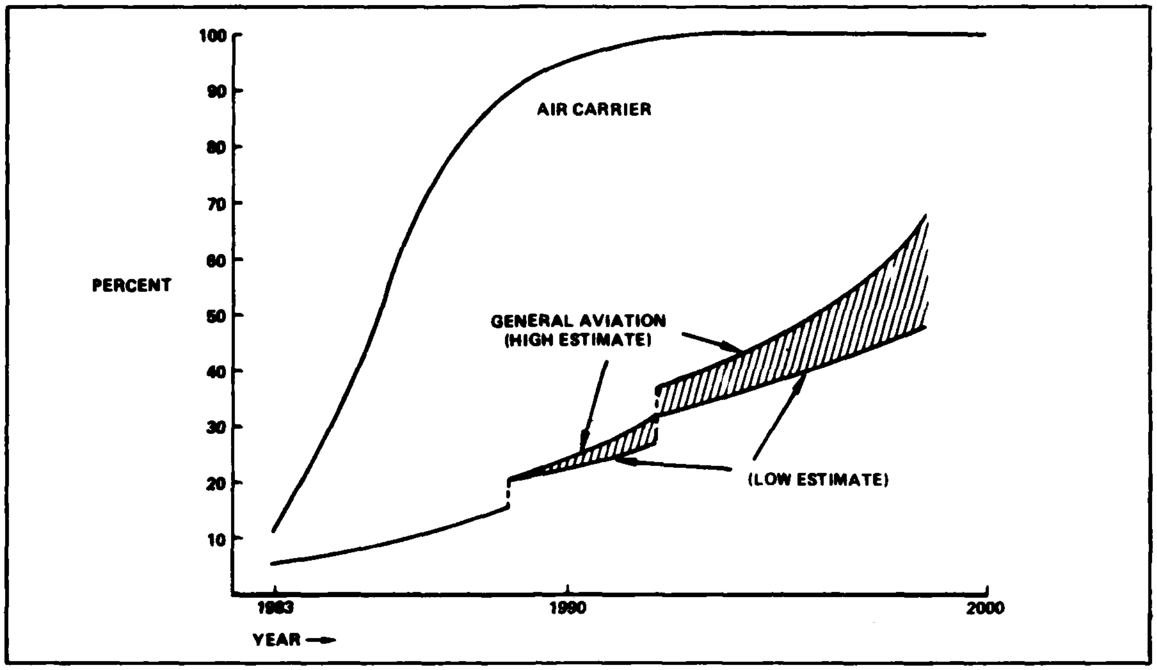

Figure 21. Estimated Cumulative RNAV Equippage Levels (by Aircraft Type)

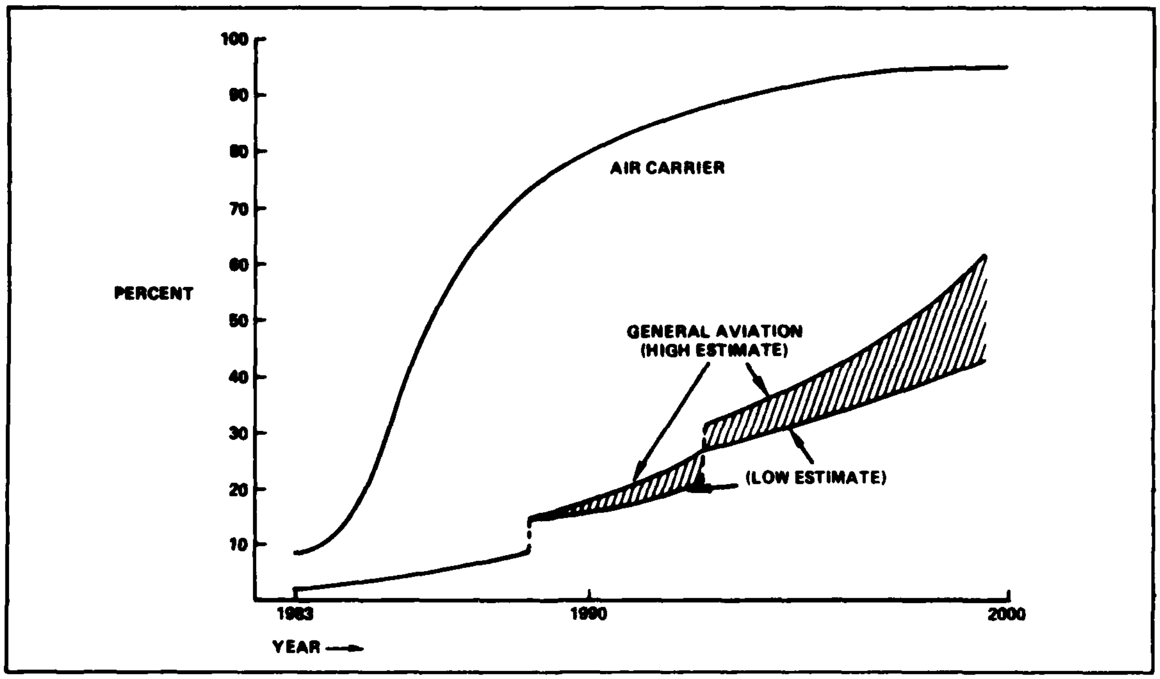

Figure 22. Estimated Cumulative Percent RNAV Navigation Utilization (by Aircraft Type)

RNAV fuel cost savings were calculated as follows. FAA 1982 Aviation Forecasts[32] were collected for air carrier and general aviation fuel consumption. For the period from 1995-2000, a straight line extrapolation (approximately 3.5 percent per year) of fuel consumption was assumed as depicted in Figure 23. There is a significant percentage of GA aircraft that uses jet fuel; however, virtually no aviation gasoline is used by air carriers. The difference in total civil fleet fuel consumption between jet fuel and aviation gasoline, therefore, provides some indication of the differences in consumption between air carriers and general aviation.

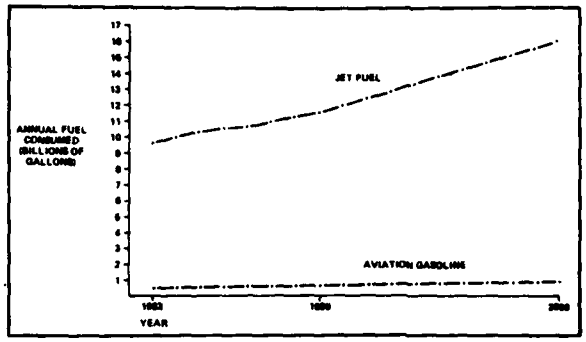

Figure 23. Estimated Total Fuel Consumption Per Year (by Fuel Type)

The percentages of utilization by year, by type of operation, were then applied to these forecast levels. An average of 2.5 percent fuel savings was then calculated, which in turn was multiplied by average air carrier fuel costs ($1 per gallon)[33] or GA fuel costs ($2.05 per gallon),[34] as appropriate, to yield total annual and aggregate fuel savings. Total discounted benefits were thus calculated to be between $1.52 and $1.55 billion dollars for the period 1983-2000. Figure 24 depicts these annual benefits.

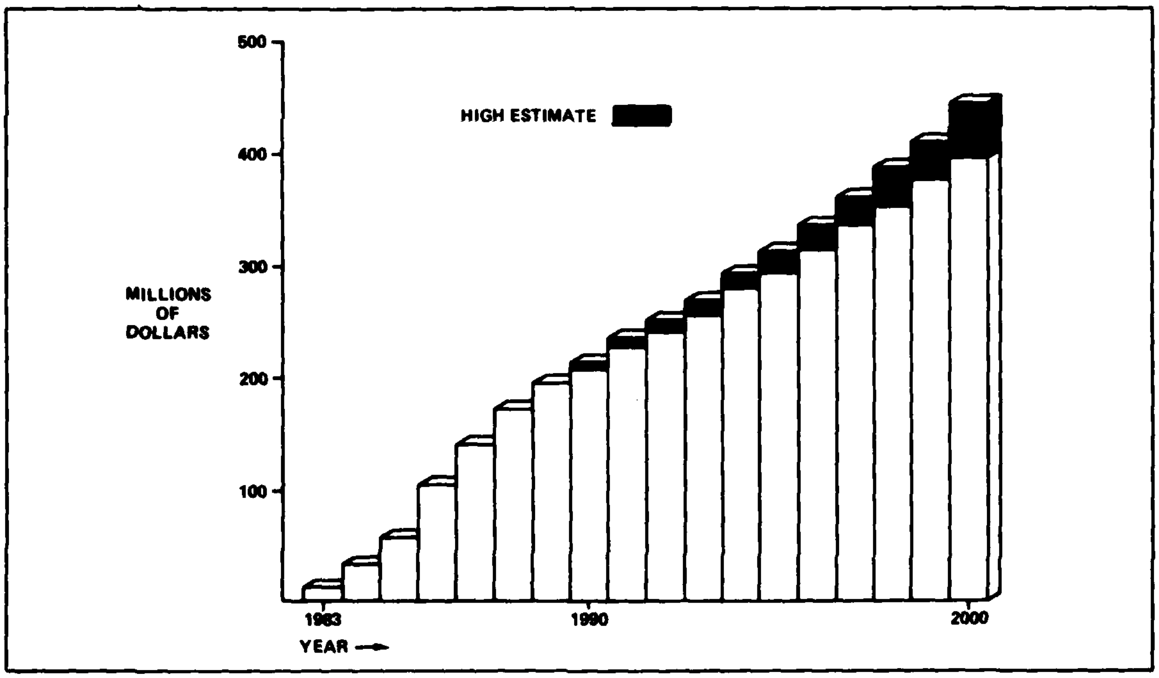

Figure 24. Total RNAV Integration Benefits by Year (Undiscounted 1983 Dollars)

[32] U.S. Department of Transportation Federal Aviation Administration, *FAA Aviation Forecasts, Fiscal Years 1983-1994*, Report No. FAA-APO-83-1, February 1983, pg. 54.

[33] *Ibid.*, pg. 21.

[34] *Ibid.*

COSTS

The cost elements[35] of Random Routes are described in more detail below.

NAR Recommendation Formulation/Program Development

NAR Task Group 1-3.1 developed the major recommendations which form this enhancement area. In addition to the task group meeting costs, FAA staff costs will be incurred in developing the ultimate program. These costs are estimated to total one hundred fifty thousand dollars.

Controller Training

FAA personnel costs will be incurred in order to enhance the RNAV segment in the current new controller curriculum (five additional hours are estimated) and to re-train a significant percentage of controllers (45 percent) now in the field.[36] These costs are estimated at approximately $30,000 per year throughout the program.

RNAV Avionics

The largest cost component associated with RNAV Integration is expected to be the costs borne by airspace system users to purchase the area navigation equipment necessary to allow random or direct RNAV operation. Costs in this category are based upon the equippage estimates noted above for air carrier and general aviation aircraft. The annual costs of RNAV avionics systems,[37] by aircraft type, are depicted in Figure 25. These costs are shown as an annual aggregation of general aviation, business jet, and air carrier acquisitions of RNAV

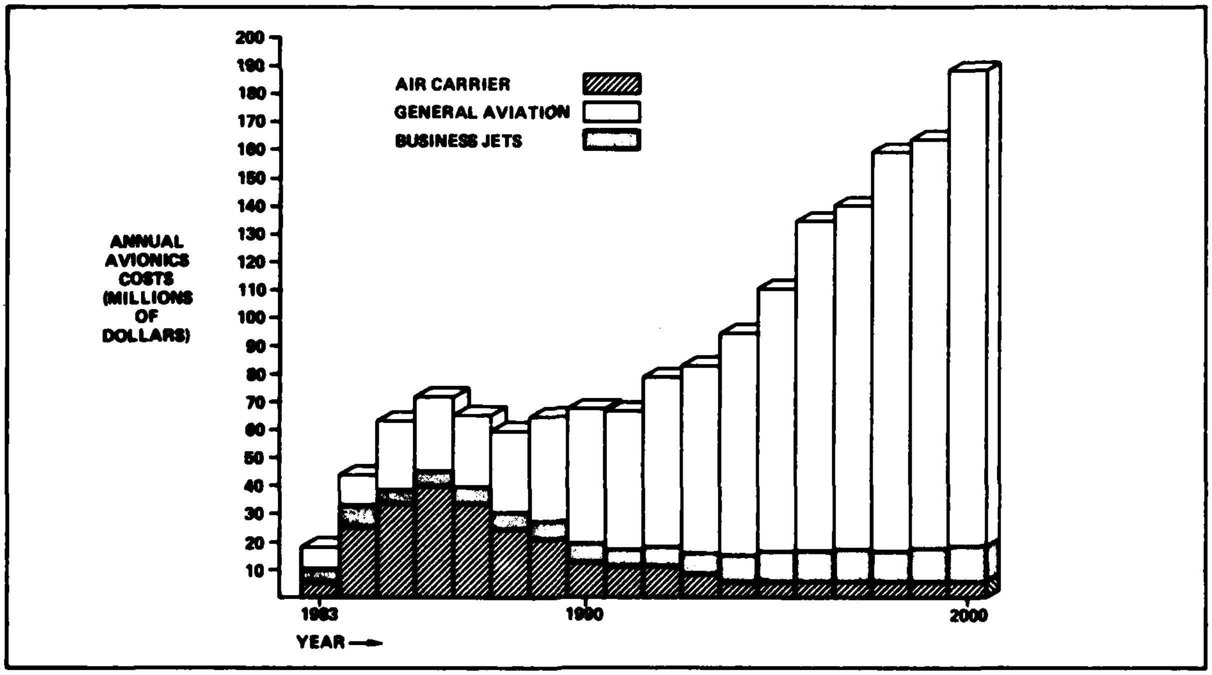

Figure 25. Annual Cost of RNAV Avionics by Aircraft Type (Undiscounted 1983 Dollars)

[35] U.S. Department of Transportation, Federal Aviation Administration, *Implementation of Area Navigation in the National Airspace System*, Final Report, FAA RD-76-196, December 1976, Chap. 5. [Hereinafter *RNAV Study*.]

[36] Estimated times are based on discussions with Headquarters ATC personnel.

[37] *Op. cit., RNAV Study.*

avionics. The totals are not cumulative from year to year.

Given the component costs, the total estimated discounted costs for the Random Routes aspect of an RNAV Integration program are between \$538 and \$676 million. These are shown in Figure 26.

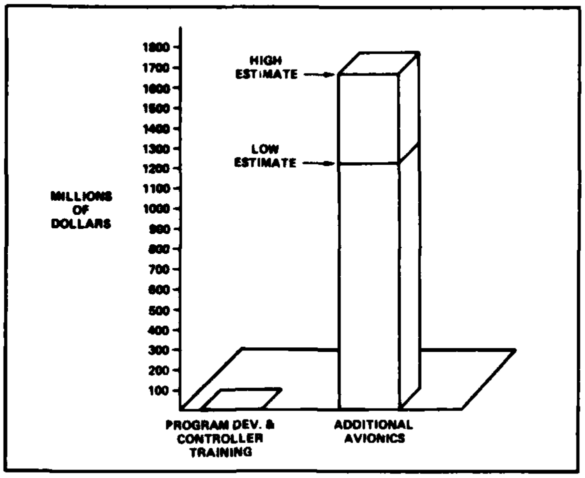

Figure 26. Total Discounted RNAV Integration Costs (1983 Dollars)

Figure 27 graphically depicts the benefit-to-cost ratio of 2.29 to 1.00 estimated for this effort.

This benefit-to-cost ratio was calculated using the low cost, low benefit and high cost, high benefit as follows:

$$\frac{\text{low benefit}}{\text{low cost}} = \frac{\$1521 \text{ million}}{\$538 \text{ million}} = 2.83$$

$$\frac{\text{high benefit}}{\text{high cost}} = \frac{\$1547 \text{ million}}{\$676 \text{ million}} = 2.29$$

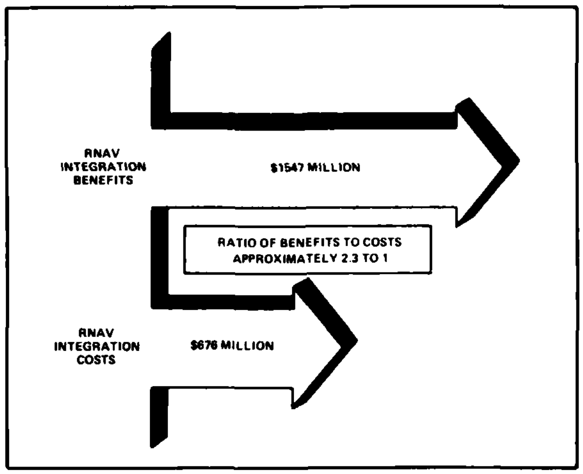

Figure 27. Benefit-Cost Ratio of RNAV Integration Enhancement Area

As can be seen the higher ratio is derived using the lower values. This directly reflects the increasing gap between percent RNAV equipped and percent utilization during the early stages of a random routes program. Indirectly, this may reflect the probability that, as random route utilization increases in the lower altitude strata, the benefits of reduced fuel consumption are lower because aviation gasoline is significantly more costly than jet fuel.

INTANGIBLES

Intangible benefits of RNAV Integration include eventual reduction in airway and route inspection/maintenance due to reduced airways and routes in the NAS, and increased pilot in-cockpit navigational awareness.

Intangible costs may include some additional effort by pilots, especially students, in order to utilize an airspace system which permits a choice among substantially different navigational methods.

CHAPTER 6

OTHER ENHANCEMENT AREAS

Seventeen additional enhancement areas have been identified to date for categorization of recommendations. In subsequent updates of this report, these areas will be analyzed in detail and aggregated with the three areas already developed to more accurately reflect NAR Program benefits and costs. These seventeen remaining enhancement areas are as follows.

Terminal

- Terminal Control Area (TCA)
- Radar Services

En Route

- Airways/Routes
- Flow Management

Flight Service System

- Aeronautical Charts
- Flight Information Publications
- Weather
- Flight Service Station

Airspace System Structure

- Infrastructure
- International Interface
- Airspace for Special Use
- Military Training Routes (MTRs)

Regulations and Standards

- Regulatory Simplification
- Regulatory Elimination
- Standards Development
- Separation Standards
- Handbooks

APPENDIX A

SUMMARY OF CURRENTLY QUANTIFIED

BENEFITS AND COSTS

FIGURE A-1.
SUMMARY OF CURRENTLY QUANTIFIED ENHANCEMENT AREA BENEFITS AND COSTS

ACTIVITY	DISCOUNTED BENEFITS	DISCOUNTED COSTS	NET BENEFITS
ARSA	\$ 84.5 M	\$ 43.9 M	\$ 40.6 M
ARTCC Resectorization	303 M	12 M	291 M
RNAV Integration: Random Routes	1,547 M	676 M	871 M
Current NAR Program Total	\$1,934.5 M	\$731.9 M	\$1202.6 M

- $\frac{\text{PROGRAM Benefits}}{\text{PROGRAM Costs}} = \frac{1934.5}{731.9} = 2.64$ Benefit/Cost Ratio of Currently Quantified ENHANCEMENT AREAS

NOTE: Net Benefits are discounted benefits - discounted costs.

APPENDIX B

REPRESENTATIVE

TASK GROUP MEETING AND NAR PROGRAM COSTS

FIGURE B-1.
NAR PROGRAM AND TASK GROUP MEETING
REPRESENTATIVE COSTS
(1983 DOLLARS)

FAA		
Labor:		
• 4 People X $226.08/dy[1] X 6[1] dys =	$ 5,426	
Travel:		
• 2 People (from eastern half of U.S.) at $400 round trip	$ 800	
• Per diem $75/dy for 8 dys (includes weekend)	600	
	1,400	
Pre/Post Meeting Activities[2]:		
• 65 dys @ $226.08/day	$14,695	
Subtotal (FAA)		$ 21,521
NARAC MEMBERS		
Labor:		
• 8 People X $280[3]/dy X 6 dys	13,440	
Travel:		
• 1 person (from mid-U.S.) at $500 round trip	500	
• Expenses ($100/dy) X 8 dys	800	
• Local Travel at $.20/mi for 10 mi for 6 dys X 9 people	108	
NARAC Travel (total)	$ 1,408	
Pre/Post Meeting Activities:		
• 3 dys @ 280/dy	6,720	
Subtotal (NARAC Members)		$ 21,568
TECHNICAL SUPPORT		$ 45,300
(Pre-meeting materials, daily summary minutes, staff studies, recommendations classification, automated recommendations tracking, computer support, EXCOM meetings, etc.)		
RELATED NAR STAFF ACTIVITIES[4]	$5,990	
TOTAL (meeting)		$94,379

[1] Based on GS14, Step 5 average salary plus 26 percent fringe benefits. Average meeting duration: 6 working days.

[2] Includes all meeting preparation activities, post-meeting report preparation, preparation of NARAC materials, EXCOM materials, and Administrator briefing, and FAA member/participant reviews.

[3] $55,000/yr X 1.26 (Fringe Benefits)/250 dys per yr = $280/dy.

[4] Averages all other NAR-related activities including travel to and participation by NAR staff in meetings and conferences held by interest groups involved in the NAR; preparation of briefings and papers for such events.

APPENDIX C

ARSA PROGRAM

BENEFITS AND COSTS

FIGURE C-1.
MIDAIR COLLISION COSTS–GENERAL AVIATION–PER AIRCRAFT (THOUSANDS OF 1983 DOLLARS)

		FATALITIES AND INJURIES						AIRCRAFT DAMAGE					
		Fatalities		Serious Injuries			Destroyed			Substantially		Collision Costs	Total of Hours Flown[5]
General Aviation	No. of Occupants[1]	Probe[2]	Cost ($653[3])	Prob[2]	Cost ($47[4])	Prob[2]	Replace Value	Exp. Cost	Prob[2]	Restor[3] Value	Exp. Cost		
Jet	4.1	.406	$1,087	.046	$ 9	.493	$1,964	$968	.400	$654	$262	2,326 X .03 =	$70
Turboprop	5.6	.406	1,485	.046	12	.493	768	379	.400	256	102	1,978 X .06 =	119
Multi-Engine Piston	3.6	.406	954	.046	8	.493	126	62	.400	42	17	1,041 X .17 =	177
Single-Engine Piston	2.2	.406	583	.046	5	.493	33	16	.400	11	4	608 X .67 =	407
Rotorcraft	2.4	.406	636	.046	5	.493	91	45	.400	31	12	698 X .07 =	49

$822 X 2 aircraft = $1,644

[1] *General Aviation and Aircraft Activity Report*, FAA-MS-79-7, Office of Management Systems, December 1979.
[2] *Annual Review of Aircraft Accident Data, U.S. General Aviation, 1969-1978* National Transportation Safety Board.
[3] *Economic Values for Evaluation of FAA Investment and Regulatory Programs*, U.S. DOT, FAA, Office of Aviation Policy and Plans, September 1981, pg. 40.
[4] *Op. Cit., Economic Values*, pg. 2729.
[5] *FAA Aviation Forecasts*, FY 1983-1994, U.S. DOT, FAA, Office of Aviation Policy and Plans, February 1983.

FIGURE C-2.
BENEFITS OF REDUCED VFR SEPARATION STANDARDS IN ARSA (BASED ON AVERAGE ARSA: 1983 DOLLARS)[1]

Year	Annual Delay Reduction (hrs.)	Total Annual Cost Avoidance	Number of ARSA Locations (arpts.)
1984	312	28,062	2
1985	4,914	441,990	30
1986	12,899	1,160,158	75
1987	25,102	2,257,668	139
1988	26,357	2,370,552	139
1989	27,675	2,489,079	139
1990	29,059	2,613,533	139
1991	30,512	2,744,210	139
1992	32,037	2,881,420	139

[1] Based on the following formula:

60 ops/dy X 3 dys/wk X 52 wks/yr = 9360 ops./yr/ARSA
9360 ops./yr X 1/60 hrs/ops. = 156 hrs/yr/ARSA
156 hrs/yr X 89.94 var-op-cst/hr(GA) = $14,031/yr/ARSA
(Operations assumed to increase by five percent per year)

FIGURE C-3.
SUMMARY OF ARSA PROGRAM BENEFITS (DISCOUNTED 1983 DOLLARS)

Year	Annual ARSA Ops. (# of Sites)	Avg. Ops. Per ARSA (10^5)	MACs Averted	GA Cost Per MAC	MAC Cost Avoidance	VFR Sep. Stan. Cost Avoidance	Total Cost Avoidance	Discount (10%)	Discounted Value
1983	–	–	–	1.644M	–	–	–	1.00	
1984	460,000(2)	2.3	.242	1.644M	397,563	28,062	425,625	.91	387,319
1985	4,080,018(30)	1.3	1.299	1.644M	2,135,427	441,990	2,577,417	.83	2,139,256
1986	12,398,218(75)	1.65	4.988	1.644M	8,199,699	1,160,158	9,359,857	.75	7,019,893
1987	24,127,015(139)	1.74	10.171	1.644M	16,721,250	2,257,668	18,978,918	.68	12,905,664
1988	25,331,216(139)	1.82	11.028	1.644M	18,130,460	2,370,552	20,501,012	.62	12,710,627
1989	26,599,940(139)	1.91	12.029	1.644M	19,776,090	2,489,079	22,265,169	.56	12,468,494
1990	27,929,937(139)	2.01	13.187	1.644M	21,678,700	2,613,533	24,292,233	.51	12,389,038
1991	29,326,432(139)	2.11	14.391	1.644M	23,658,590	2,744,210	26,402,800	.47	12,409,316
1992	30,792,753(139)	2.22	15.769	1.644M	25,924,830	2,881,420	28,806,250	.42	12,098,625
Total			83.104				153,609,281		84,458,232

FIGURE C-4.
COSTS OF INCREASES IN DELAYS (BASED ON ARSA AVERAGE; 1983 DOLLARS)

Year	Number of ARSA Locations	VFR Departure Delay Increase[1]	Total Annual Dollar Costs	VFR Arrival Sequencing Delay Increase[2]	Total Annual Dollar Costs	Entry Delay Increase[3]	Total Annual Dollar Costs
1984	2 arpts.	720 hrs.	$ 42,444	624 hrs.	$ 56,123	260 hrs.	$ 23,384
1985	30 arpts.	11,340 hrs.	668,493	9,825 hrs.	883,661	4,095 hrs.	368,304
1986	75 arpts.	29,768 hrs.	1,754,794	25,799 hrs.	2,320,362	10,749 hrs.	966,765
1987	139 arpts.	57,928 hrs.	3,414,829	50,202 hrs.	4,515,191	20,917 hrs.	1,881,307
1988	139 arpts.	60,823 hrs.	3,585,494	52,712 hrs.	4,740,952	21,963 hrs.	1,975,372
1989	139 arpts.	63,863 hrs.	3,764,724	55,348 hrs.	4,977,999	23,062 hrs.	2,074,141
1990	139 arpts.	67,057 hrs.	3,952,960	58,116 hrs.	5,226,899	24,215 hrs.	2,177,848
1991	139 arpts.	70,410 hrs.	4,150,608	61,021 hrs.	5,488,244	25,426 hrs.	2,286,740
1992	139 arpts.	73,930 hrs.	4,358,188	64,072 hrs.	5,762,656	26,696 hrs.	2,401,115

[1] Based on following formula:

- .3 operations affected x 200 operations/dy x 360 dys/yr = 21,600 ops/yr./ARSA
- 1/60 hr./operation x 21,600/yr = 360 hrs./yr./ARSA
- 360 hr/yr x $58.95 crew cost/hr. = $21,222/yr./ARSA

[2] Based on following formula:

- 60 arr ops/dy x 4 dys/wk x 52 wks/yr = 12,480 ops/yr./ARSA
- 1.5/60 hrs./op x 12,480 ops/yr = 312 hrs./yr./ARSA
- 312 hrs./yr x 89.94 var op cst (ga) = $28,061/yr./ARSA

[3] Based on following formula:

- 50 ops/wk x 52 wks/yr = 2,600/yr.
- 2,600 ops/yr x 3/60 hr./op = 130 hr/yr.
- 130 hrs./yr x $89.94 voc (ga)/hr = $11,692

FIGURE C-5.
OPERATIONAL CONFIRMATION,
TRAINING AND EDUCATION
PROGRAMS COST
PROGRAM TOTAL (1983 DOLLARS)

OPERATIONAL CONFIRMATION (Study design, survey data collection, evaluation support; 1984)	$500,000
TRAINING & EDUCATION	
$20,000 PER ARSA SITE (Based on APO study)	
• 2 (in 1984) x $20,000:	$40,000
• 28 (in 1985) x $20,000:	$560,000
• 45 (in 1986) x $20,000:	$900,000
• 64 (in 1987) x $20,000:	$1,280,000
TOTAL	$3,280,000

FIGURE C-6.
SUMMARY OF ARSA PROGRAM COSTS
(DISCOUNTED 1983 DOLLARS)

Year	NAR Program	Train'g & Educ.	VFR Dep. Delay	VFR Arr. Seq'g Delay	VFR Entry Delay	ARSA Total	Discount (10%)	Discounted Value
1983	$188,658					$ 188,658	1.00	$ 188,658
1984		$ 540,000	$ 42,444	$ 56,123	$ 23,384	$ 161,951	.91	602,375
1985		560,000	668,493	883,661	368,304	2,480,458	.83	2,058,780
1986		900,000	1,754,794	2,320,362	966,765	5,941,921	.75	4,456,441
1987		1,280,000	3,414,829	4,515,191	1,881,307	11,091,327	.68	7,542,102
1988			3,585,494	4,740,952	1,975,372	10,301,818	.62	6,387,127
1989			3,764,724	4,977,999	2,074,141	10,816,864	.56	6,057,444
1990			3,952,960	5,226,899	2,177,848	11,357,707	.51	5,792,431
1991			4,150,608	5,488,244	2,286,740	11,925,592	.47	5,605,028
1992			4,358,188	5,762,656	2,401,115	12,521,959	.42	5,259,223
TOTAL								$43,949,609

APPENDIX D

ARTCC RESECTORIZATION

BENEFITS AND COSTS

FIGURE D-1.
LABOR AND EQUIPMENT COST AVOIDANCE FROM RESECTORIZATION (1983 DOLLARS)[1]

Year	Labor Cost Avoidance	Equip. Cost Avoidance	Annual Total
1983	$13,820,375[2]	$ 5,136,750	$18,957,375
1984	55,282,500	15,410,250[3]	70,692,750
1985	55,282,500	0	55,282,500
1986	55,282,500	0	55,282,500
1987	55,282,500	0	55,282,500
1988	55,282,500	0	55,282,500
1989	55,282,500	0	55,282,500
1990	55,282,500	0	55,282,500

[1] Based on the following formulas:

Manpower
[avg. 11.7 controllers/sector @ $35,000]
11.7 x $35,000 x 135 sectors = $55,282,500.

Equipment
[1 PVD/sector @ $152,000/sector]
$152,200/sector x 135 sectors = $20,547,000

[2] Twenty-five percent of maximum annual labor and equipment cost avoidance realized in first year.

[3] Remaining seventy-five percent of equipment cost avoidance realized in second year. Amortization over a longer period not warranted because of pre-resectorization need to replace PVDs in near term rather than over an extended period.

FIGURE D-2.
COSTS OF IMPLEMENTING ARTCC RESECTORIZATION PROGRAM (1983 DOLLARS)[1]

Program Development, sector re-design, briefings, reviews: 1103 mandays	
1103 mn-dy x 193.25[2] /mn-dy =	$213,155
Implementation (Indianapolis Center Consolidation Staff Study estimate)	
46,000 to 66,000 mn-dy x $193.2 =	$8,889,500 - $12,754,500
Travel[3] /$70,000 x 1.055 (CPI increment)) =	$73,850
Equipment	
• *Video Maps* ($500/ARTCC) =	$20,000
• Sector relocation/reallocation ($8,000/Sector; 135 Sectors Total)	
1982: 34 Sectors (at year end) x $8,000/Sector =	$272,000
1983: 101 Sectors (at year end) x $8,000/Sector =	$808,000
Total Costs (Undiscounted)	$10,276,505 to $14,141,505

[1] AAT-300 *memorandum summarizing* headquarters and field studies estimating Resectorization Program costs, May, 1982.

[2] Based on 1982 average $183.18 per specialist per day multiplied by CPI average increase of 5.5 percent.

[3] Travel funds provided by NAR budget.

FIGURE D-3.
SUMMARY OF BENEFITS AND COSTS: ARTCC RESECTORIZATION

Years	Annual Benefits	Discount	Discounted Value	Annual Costs	Discount	Discounted Value
1982				9,468,505–		13,333,505
1983	18,957,375	1.00	18,957,375	808,000	1.00	808,000
1984	70,692,750	.91	64,330,402	0	.91	0
1985	55,282,500	.83	45,884,475	0	.83	0
1986	55,282,500	.75	41,754,872	0	.75	0
1987	55,282,500	.68	37,996,933	0	.68	0
1988	55,282,500	.62	34,577,209	0	.62	0
1989	55,282,500	.57	31,465,260	0	.57	0
1990	55,282,500	.51	28,633,386	0	.51	0
TOTAL			$303.6 M			$10.28-14.14 M

APPENDIX E

RNAV INTEGRATION: RANDOM ROUTES

BENEFITS AND COSTS

FIGURE E-1.
ESTIMATES OF AIRCRAFT EQUIPPAGE LEVELS (RNAV AVIONICS) AND RNAV OPERATION RATES, 1983-2000

	Air Carrier		General Aviation			
			Business Aircraft		Other GA	
Year	% Equipped	% Use (RNAV)	% Equipped	% Use (RNAV)	% Equipped	% Use (RNAV)
1983	12	8	6	1	6	1
1984	25	13	7	2	7	2
1985	40	25	9	4	9	4
1986	60	45	11	5	11	5
1987	75	60	13	6	13	6
1988	85	68	15	8	15	8
1989	92	75	21/21+	15/17	21/21+	15/17
1990	95	80	23/24	16/18	23/24	16/18
1991	97	82	24/26	17/20	24/26	17/20
1992	99	84	26/29	18/22	26/29	18/22
1993	100	87	28/32	19/24	28/32	19/24
1994	100	89	32/38	27/32	32/38	27/32
1995	100	90	34/42	29/35	34/42	29/35
1996	100	92	36/47	31/38	36/47	31/38
1997	100	93	38/53	33/44	38/53	33/44
1998	100	94	42/60	36/50	42/60	36/50
1999	100	95	46/67	40/57	46/67	40/57
2000	100	95	51/75	44/65	51/75	44/65

FIGURE E-2.
ESTIMATED RANDOM ROUTES FUEL CONSUMPTION SAVINGS 1983-2000 (1983 DOLLARS)[1]

Year	Cost Savings (millions)	Discount Factor	Discounted Value (millions)
1983	17.77	1.00	17.77
1984	30.21	.91	27.49
1985	59.39	.83	49.29
1986	107.02	.75	80.23
1987	145.16	.68	98.71
1988	169.80	.62	105.28
1989	196.81/198.24	.56	110.21/111.01
1990	214.44/215.92	.51	109.36/110.12
1991	227.12/229.47	.47	106.75/107.85
1992	240.19/143.45	.42	100.88/102.25
1993	256.65/260.93	.39	100.09/101.76
1994	278.79/283.24	.35	97.58/99.13
1995	294.77/300.33	.32	94.33/96.11
1996	314.67/321.41	.29	91.25/93.21
1997	332.50/343.52	.26	86.45/89.32
1998	352.19/366.82	.24	84.53/88.04
1999	374.18/392.59	.22	82.32/86.37
2000	393.63/417.27	.20	78.73/83.45
			152[illegible]5/1547.39

[1] Dollar cost savings were derived using the following formula in each year:

Estimated gallons used by A/C x estimated RNAV utilization rate (see Figure E-1) x 2.5 percent x $1.00/gal. = A/C fuel savings

Estimated gallons used by GA x estimated RNAV utilization rate (see Figure E-1) x 2.5 percent x $2.05/gal. = GA fuel savings

A/C savings + GA savings = Total annual fuel savings

FIGURE E-3.
RANDOM ROUTES RNAV PROGRAM
DEVELOPMENT COSTS
(1983 DOLLARS)

NAR Meeting:	$94,379
HQ & Regional Staff:	
Program Development and Review (HQ) (230 mn.-dys @ $225/dy) =	$51,750
(1/2' 1983; 1/2 1984)	
Program Reviews and Briefings (Regions) (30 mn.-dys $225/dy) =	$6,750
(1/2' 1983; 1/2 1984)	
Subtotal Program Development =	$152,879

FIGURE E-4.
CONTROLLER RNAV TRAINING COSTS
(1983 DOLLARS)[1]

- New Controller Training:
  - [additional 5 hrs. at Okla. City Training Center per controller trainee ($16.25/hr)[2]; FAA trainer ($28.25/hr)[3]]
  - 5 hrs. x $10.43/hr x 500 controllers/yr = $26,075
  - 5 hrs. x $28.25/hr x 25 trn'g classes/yr = $3,531

$29,606/yr.
(each year of program)

SUBTOTAL

- Re-training for RNAV
  - 45% of controllers each require 3 hrs. training
  - total trainer time = 1mn.-yr
    - 5000 controllers x 3 x 23.02/[4] hr. = $345,300
    - 1 FAA mn-yr = $117,000

SUBTOTAL $462,300 (1984 only)

[1]Hour estimates based on Headquarters ATC personnel judgment.

[2]GS 7 entry level plus 26 percent fringe benefits.

[3]GS 14 average plus 26 percent fringe benefits.

[4]$38,000 per year average controller salary plus 26 percent fringe benefits.

FIGURE E-5.
COSTS OF RNAV AVIONICS TO AIR CARRIERS AND GA OPERATORS, 1983-2000

Year	Number of A/C Aircraft Equipped[1]	Cost[2] (000)	Number of Bus. Jet Aircraft Equipped[1]	Cost[3]	Number of GA Aircraft Equipped[1]	Cost[4]	Total Cost (Undiscounted)
1983	60	4,878	750	5,625	1350	8,438	18,941
1984	331	26,910	750	5,625	1763	11,019	43,554
1985	395	32,114	800	6,000	4043	25,269	63,383
1986	480	39,024	800	6,000	4280	26,750	71,774
1987	412	33,496	800	6,000	4400	27,500	66,996
1988	298	24,227	800	6,000	4690	29,313	59,540
1989	251	20,406	850/950	6,380/7,130	5050/6125	31,563/38,281	58,349/65,817
1990	152	12,358	850/950	6,380/7,130	5150/7697	32,188/48,106	50,926/67,594
1991	127	10,325	850/950	6,380/7,130	5350/8048	33,438/50,300	50,143/67,755
1992	131	10,650	900/1000	6,750/7,500	6600/9800	41,250/61,250	58,650/79,400
1993	105	8,537	950/1000	7,130/7,500	8400/10,978	52,500/68,613	68,167/84,650
1994	70	5,866	950/1100	7,130/8,250	8702/12,941	54,375/80,881	67,193/94,819
1995	70	5,866	1000/1200	7,500/9,000	9096/15,106	56,850/94,413	70,038/109,101
1996	70	5,866	1000/1500	7,500/11,250	9450/18,872	59,100/117,950	72,288/134,888
1997	70	5,866	1000/1500	7,500/11,250	9816/19,535	61,350/122,094	74,538/139,032
1998	70	5,866	1100/1500	8,250/11,250	13,601/22,577	85,006/141,106	91,519/158,044
1999	70	5,866	1200/1600	9,000/12,000	13,981/23,316	87,381/145,725	102,069/163,413
2000	70	5,866	1300/1800	9,750/13,500	15,846/27,063	99,038/169,144	114,476/188,332
TOTAL							1,202,544/1,677,033

[1] Number to be equipped is based on the following formula:
Total aircraft (by type) projected x percent RNAV equipped (see Table D-1).
Projections derived from FAA Aviation Forecasts FY 1983-1994, pg. 29 (air carrier) and pgs. 16 and 17 (business jet and general aviation).
Projections for 1995-2000 based on straight line extrapolation.

[2] $81,300 per aircraft; RNAV Study, p. 5-22. Study figure was inflated to reflect increase from 1976 to 1983.
[3] $7,500 per aircraft; RNAV Study, p. 5-22. Inflated to 1983.
[4] $6,250 per aircraft; RNAV Study, p. 5-23. Inflated to 1983.

FIGURE E-6.
SUMMARY OF COSTS FOR RANDOM ROUTES ASPECT OF RNAV INTEGRATION
DISCOUNTED 1983 DOLLARS)

Year	Program Dev.	Controller Training	Additional Avionics (000)	Total (000)	Discount	Discounted Value (000)
1983	123,629		18,941	19,065	1.00	19,065
1984	29,250	491,906	43,554	44,075	.91	40,108
1985		29,606	63,383	63,413	.83	52,633
1986		29,606	71,774	71,804	.75	53,853
1987		29,606	66,996	67,026	.68	45,578
1988		29,606	59,540	58,638	.62	36,356
1989		29,606	58,349/65,817	58,379/65,847	.56	32,692/36,874
1990		29,606	50,926/67,594	50,956/67,624	.51	25,988/34,488
1991		29,606	50,153/67,594	50,173/67,784	.47	23,581/31,858
1992		29,606	58,650/79,400	58,680/79,430	.42	24,646/33,361
1993		29,606	68,167/84,650	68,207/84,680	.39	26,601/33,025
1994		29,606	67,193/94,819	67,223/94,849	.35	23,508/33,197
1995		29,606	70,038/109,101	70,068/109,131	.32	22,422/34,922
1996		29,606	72,288/134,888	72,318/134,918	.29	20,927/39,126
1997		29,606	74,538/139,032	74,568/139,062	.26	19,388/36,156
1998		29,606	91,519/158,044	91,549/158,074	.24	21,972/37,938
1999		29,606	102,069/163,413	102,099/163,443	.22	22,462/35,957
2000		29,606	114,476/188,332	114,506/188,362	.20	22,901/37,672
Totals						538,222/675,689

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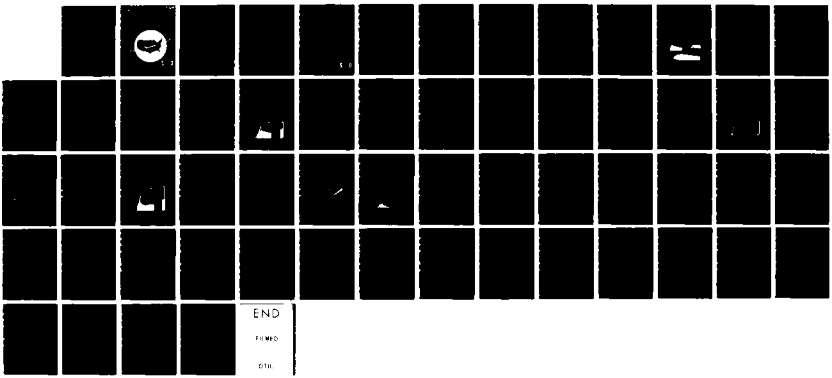

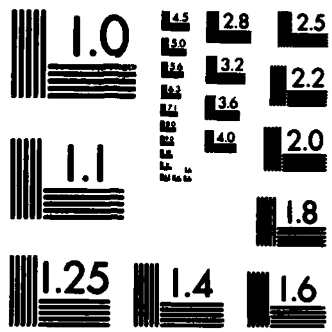

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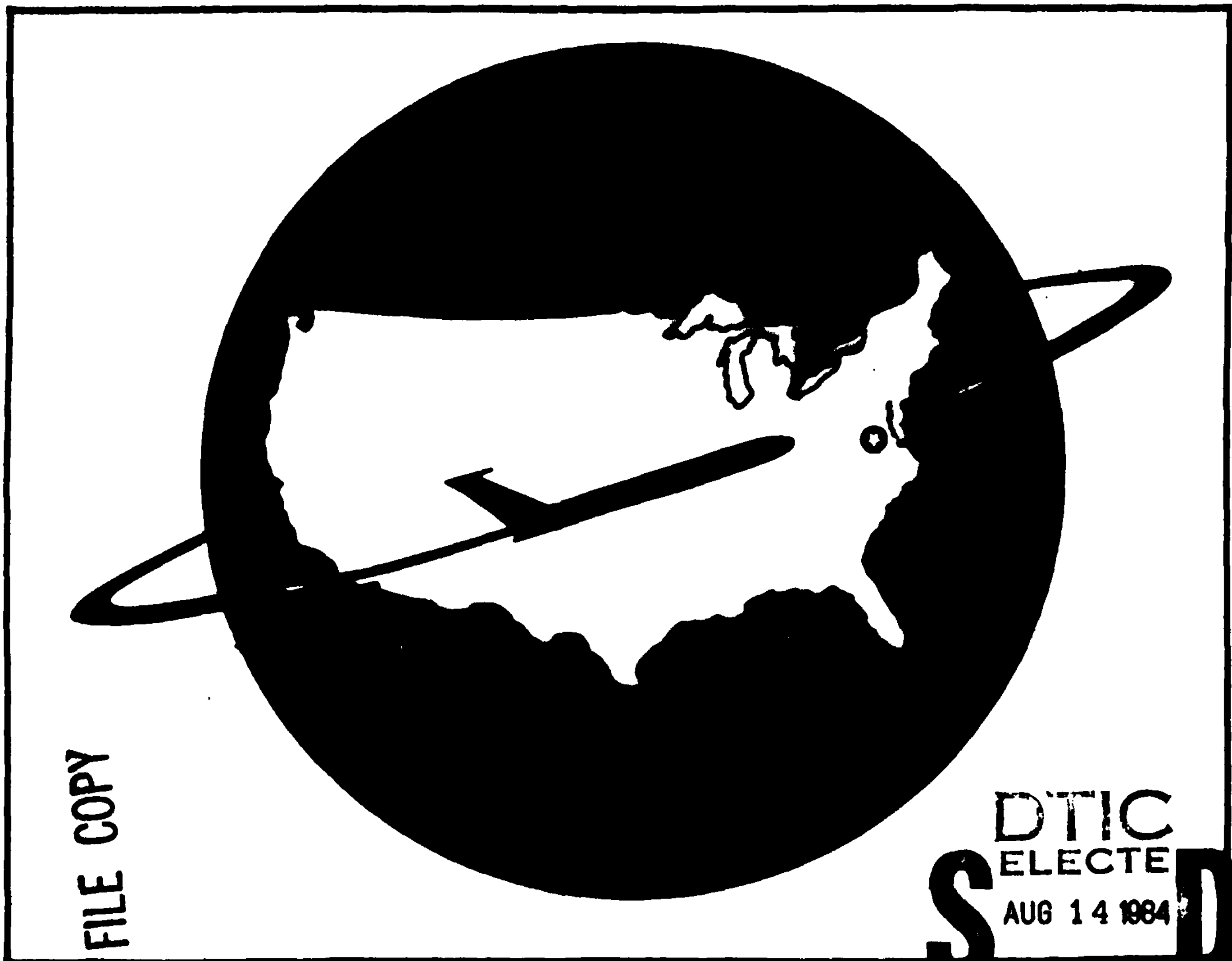
U.S. Department
of Transportation
**Federal Aviation
Administration**

NATIONAL AIRSPACE REVIEW

Benefits and Costs

Report No. DOT/FAA/AT-84/1

By
Engineering & Economics
Research Inc.



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16. Abstract

Three of the twenty enhancement areas identified for implementation within the National Airspace Review (NAR) are evaluated as to their benefits and costs. These areas are Airport Radar Service Area (ARSA), ARTCC Resectorization, and the Random Routes aspect of area navigation (RNAV) Integration. A methodological approach to evaluation of benefits anc costs, suitable for application to all enhancement areas, is developed. Each of the three areas covered in this report is treated in detail in the report and supported by quantitative data placed in appendices.

Two other reports should be considered in conjunction with this report: the NAR Interim Report and the NAR Implementation Plan. Updates of this report are anticipated each six months.

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ARTCC Resectorization
Random Routes

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NATIONAL AIRSPACE REVIEW BENEFITS AND COSTS

by

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Prepared for

Federal Aviation Administration
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May 1984

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EXECUTIVE SUMMARY

The National Airspace Review (NAR) is a cooperative venture of the aviation industry and government. Using a synergistic approach, the NAR is comprehensively reviewing air traffic control procedures, flight regulations, and airspace for the purpose of validating the current system or identifying near-term changes which will promote greater efficiency. As a component of the *National Airspace System Plan (NAS Plan)*, the NAR will provide the operational framework for moving into the next generation National Airspace System.

With over 600 recommendations now formally developed, there is a recognized need for an assessment of the program's benefits and costs which will evaluate progress to date. This report should be read in conjunction with the *NAR Interim Report* and *NAR Implementation Plan* in order to gain a more detailed understanding of the NAR program and process.

The "Enhancement Area" classification developed for the *NAR Implementation Plan* provides a comprehensive grouping of recommendations and is the basis upon which the benefit and cost identification and quantification is made. Of the twenty enhancement areas identified to date, the Airport Radar Service Area (ARSA), Air Route Traffic Control Center (ARTCC) Resectorization, and Random Routes aspect of the area navigation (RNAV) Integration Enhancement Areas have been evaluated to determine benefit-to-cost ratios.

Each enhancement area is broken down into quantifiable benefits and costs which are then individually evaluated. The results of this step are then aggregated so as to compare benefits and costs for the area as a whole.

AIRPORT RADAR SERVICE AREA (ARSA)

ARSAs are intended to replace Terminal Radar Service Area (TRSA) airspace with a simplified airspace configuration and mandatory communications requirement. The dollar value of cost savings arising from ARSAs is estimated based upon ARSA implementation at all 139 current TRSAs and is expected to be realized until 1992. Benefits are estimated to total $84.5 million in discounted 1983 dollars.

The costs associated with implementing and operating ARSAs are comprised of various types of delay experienced by VFR aircraft and training/educating controllers and pilots. These costs are estimated to total $43.9 million in discounted 1983 dollars. The estimated ARSA benefit-to-cost ratio is thus 1.92 to 1.00.

ARTCC RESECTORIZATION

The ARTCC Resectorization Program was undertaken to streamline and reduce the number of en route sectors in an effort to improve current controller productivity, improve traffic flow efficiency, enhance current automation capabilities, and assist in positioning the air traffic control system for future technological improvements envisioned in the *NAS Plan*.

The primary quantified benefits of resectorization are avoided controller labor costs and attendant avoided equipment costs. These are estimated based on a reduction of 135 sectors and are expected to continue until 1990. Benefits are estimated to total $303 million in discounted 1983 dollars.

The costs of resectorization have already been incurred and are comprised mainly of labor hours for implementation. The total cost is estimated to be $12 million in discounted 1983 dollars.

The benefit-to-cost ratio of the program is estimated to be 25.25 to 1.00, exclusive of intangible benefits to the system arising from the program.

RNAV INTEGRATION: RANDOM ROUTES

RNAV Integration is a broad enhancement area, elements of which are scheduled for implementation as late as 1988. The Random Routes aspect of this enhancement area is evaluated in this report.

The Random Route aspect of RNAV Integration is a set of activities directed toward enhancing pilot use of, and controller ability to accommodate, increased random area navigation in flight.

The primary benefit from undertaking such actions will be reduced fuel consumption. Based on fleet makeup, size, and increasing rate of RNAV utilization, this reduction is estimated to total $1.547 billion in discounted 1983 dollar benefits for the 17-year period to 2000.

Costs include program development, controller and pilot training, and RNAV avionics. Together these costs are estimated to total $676 million in discounted 1983 dollars through 2000.

The estimated benefit-to-cost ratio (low order) for this Enhancement Area is 2.29 to 1.00.

Figure 1 presents a summary of these estimated enhancement area benefits and costs. Note that these three areas combined represent a net cost avoidance/savings of $1,202.6 million.

Future semi-annual updates of this document will evaluate additional enhancement areas leading to an ultimate ratio for the entire program. A tabular summary of the enhancement areas quantified to date is presented in Appendix A.

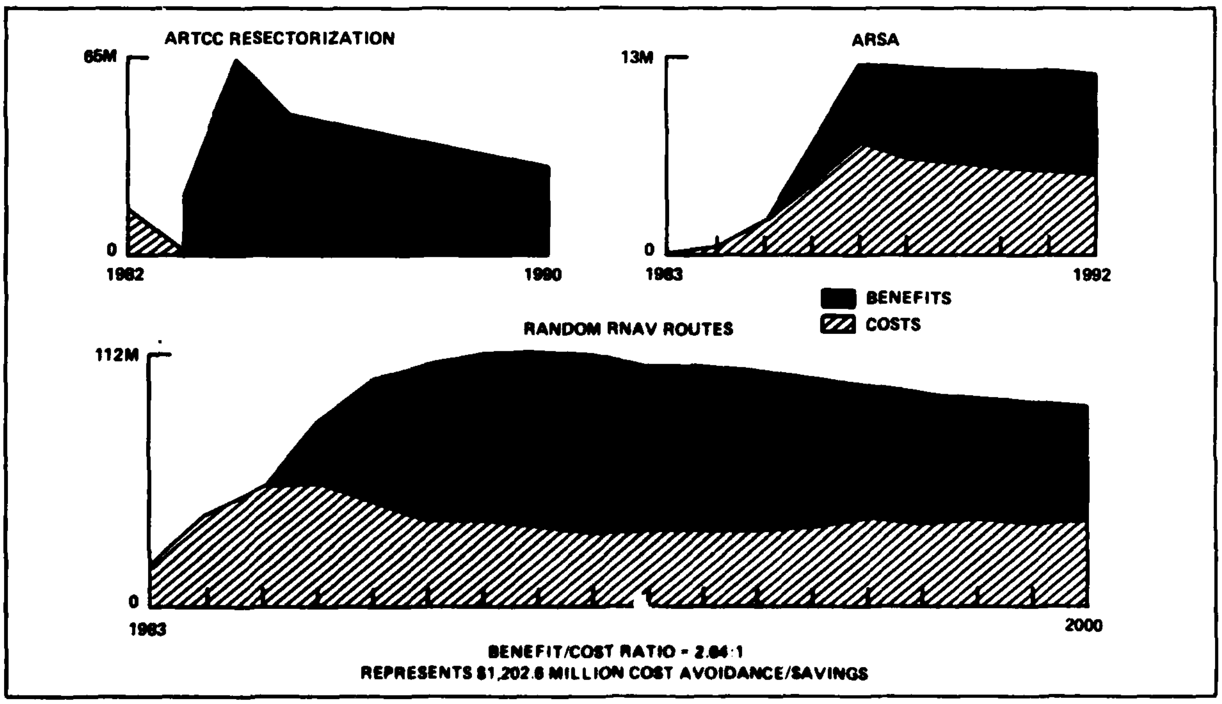

Figure 1. Summary of Quantified Enhancement Area Benefits and Costs

CHAPTER 1
INTRODUCTION

The National Airspace Review (NAR) is a cooperative venture of the aviation industry and government. Using a synergistic approach, the NAR is comprehensively reviewing air traffic control procedures, flight regulations, and airspace for the purpose of validating the current system or identifying near-term changes which will promote greater efficiency. As a component of the *National Airspace System Plan (NAS Plan)* the NAR will provide the operational framework for moving into the next generation National Airspace System.

Since its inception in 1981, the NAR Program has operated with a small staff developing approaches to problem identification, task group meeting organization, special analyses, and implementation of recommendations. With the assistance of Engineering and Economics Research, Inc., the staff has planned and implemented over 40 task group sessions, the membership of which has been comprised of various aviation, military, governmental, and labor organizations. These task groups have generated over 600 recommendations for enhancements to airspace, flight regulations, or procedures. Validation of many aspects of the current system has also taken place. Despite changes to the NAR agenda and adjustments necessitated by some task group recommendations and other special requests, the NAR Program has remained within budget in each year of operation.

The National Airspace Review is directly related to the *NAS Plan*. The *NAS Plan* was developed in response to the "compelling problems of how best to accommodate spiraling demands for aviation services, constrain costs, recast the required technical framework, and deal with aging facilities."[1] In short, the plan was undertaken because expected future system operating costs without the plan were estimated to reach $2 billion per year more than with the plan.[2] Similarly, the NAR has undertaken to provide the near term equivalent of the *NAS Plan*: accommodating user demand and constraining costs through operational and regulatory improvements to the Air Traffic Control (ATC) system. The *NAS Plan* is specifically geared to accommodate NAR task group recommendations[3] and consideration of the *NAS Plan* in NAR task group recommendations has been assured through participation by NAR Program Management Staff (PMS) representatives in task group meetings.

Consistent with the NAR Program objectives, and with over 600 recommendations now formally developed, there is a need for an assessment of the program's benefits and costs, both as to its immediate effects and as the program progresses. As a first step in this assessment process, it is important to categorize recommendations so that groups of recommendations that are interrelated are assessed as a whole and so that a better understanding of the types of benefits and costs that might be realized may be obtained.

A classification approach that has been developed within the *NAR Implementation Plan*[4] is

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[1] U.S. Department of Transportation, Federal Aviation Administration, *National Airspace System Plan*, April 1983, Executive Summary.

[2] *Ibid.*, chart, pg. I-38.

[3] *Ibid.*, Executive Summary.

[4] U.S. Department of Transportation, Federal Aviation Administration, *NAR Implementation Plan*, January, 1983, pg. 1-1. (Hereinafter, *Implementation Plan*)

the System Area/Enhancement Area classification. This approach groups recommendations with a focus on the results of their implementation and also largely parallels the *NAS Plan* organization. Moreover, this classification approach provides a comprehensive overview of the expected outcome of the NAR Program and will be used to guide analysis of the benefits and costs of NAR recommendations. To date, twenty enhancement areas have been developed to fully contain all current NAR recommendations.

This report presents analyses of the Airport Radar Service Area (ARSA) and ARTCC Resectorization Enhancement Areas, as well as an analysis of the Random Routes aspect of the area navigation (RNAV) Integration Enhancement Area. Additional enhancement areas will be analyzed in future updates of this report. Updates are currently scheduled to occur semiannually.

The remaining chapters cover methodological approach (Chapter 2), the ARSA Enhancement Area (Chapter 3), the ARTCC Resectorization Enhancement Area (Chapter 4), and Random Routes within the RNAV Integration Enhancement Area (Chapter 5). The appendices following the report contain the detailed information upon which this benefit-cost analysis relies in part.

This benefit-cost analysis is one of three reports that should be read together. Along with the *NAR Implementation Plan*, this report is built on the foundation laid in the *NAR Interim Report* and should be read in that light. More extensive information on the NAR Program, its structure, process, and implementation timetable may be obtained by reference to these other reports.

CHAPTER 2
ANALYTIC METHODOLOGY

INTRODUCTION

The process of analyzing the benefits and costs of NAR enhancement areas begins with defining what an aviation-related benefit and cost is and then evaluating each enhancement area based on these definitions.

BENEFITS

A NAR enhancement area benefit is one that improves overall system operating efficiency, increases capacity, reduces delay, or increases safety. These types of benefits constitute the broad categories within which the benefits of the NAR Program recommendations are evaluated. They are assisting in the identification of the specific benefits which can be expected to be realized in each NAR enhancement area. Examples of benefits that fall into each of these categories include the following:

- Safety Increases
  - Reduction in midair collisions (MACs)
- Capacity Increases/Delay Reductions
  - VFR separation standards changes in ARSAs allowing reduced VFR delays in ARSAs
- System Efficiency Increases
  - Fuel savings from increased random area navigation (RNAV)
  - Enhanced controller and system effectiveness due to ARTCC sector boundary realignments that more accurately follow major traffic flow patterns

COSTS

Costs associated with the development and implementation of NAR enhancement areas include those arising from operation in the resulting revised ATC environment. These costs have been captured by conceptualizing NAR enhancement area implementation activities in terms of their "life-cycle" effects. It is generally considered that life cycle costs fall into four main categories:[5]

1. Research and Development
2. Investment (Project Start-up)
3. Operations and Maintenance
4. Termination

The NAR Program and its enhancement areas will be evaluated primarily by utilizing the first three of these four areas as the general basis for cost identification. Termination costs are normally only associated with capital- or equipment-intensive undertakings. The NAR is primarily concentrated on non-capital intensive improvements, and thus termination costs are very unlikely to arise. Task group costs, near term project design/initiation costs, and implementation costs borne by FAA are included in the research and development category.

It should be noted that these life-cycle costs are not in all cases fully chargeable to the NAR

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[5]U.S. Department of Transportation, Federal Aviation Administration, *Economic Analysis of Investment and Regulatory Decisions—A Guide*, Report No. FAA-APO-82-1, January, 1982, Chapter 4, pg. 4-6.

or to implementation of the recommendations that constitute a particular enhancement area. Many activities, projects, and new initiatives are constantly underway within FAA. Invariably, some actions necessary for one initiative will assist in achievement of another. It is felt that some activities necessary for implementation of NAR recommendations would be undertaken in any event and that, therefore, some of the NAR implementation costs should properly not be charged to the NAR. While not measured here explicitly, such cost considerations are nevertheless important in the final decision-making process.

INTANGIBLE BENEFITS AND COSTS

Intangible benefits and costs arising from improvements to the system should be considered —those for which meaningful dollar estimates cannot be generated. In particular, intangible benefits fall generally into the category of system efficiency improvements. For instance, benefits such as improvements arising from regulatory simplification or elimination are mainly intangible. Elimination or simplification of a part of the Federal Aviation Regulations (FARs) does not usually provide quantifiable time or labor savings but might, nevertheless, ease the burden of study and education required of pilots operating in the NAS. Such benefits should be considered in an overall judgment of a given project or activity.

A variety of intangible benefits are being, and will continue to be, realized as a result of the NAR Program. Because these are not specifically assignable to any particular enhancement area, but rather are associated with the NAR Program generally, they are listed here to be considered as part of each specific NAR project or activity.

- The NAR Program is an effective vehicle for user/provider communication. Through a comprehensive review/analysis of the current system, it affords timely, efficient, and coordinated input to the review plan, task group studies, and proposed action notices, and encourages the identification of problems and responsive near-term system adjustments.

- The NAR Program provides up-to-date documentation through Advance Information Packages, task group minutes and staff studies, and implementation studies.

- The NAR Program enhances effective and integrated communication across functional lines among all FAA entities.

- The NAR Program provides an efficient forum in which concepts and proposals can be considered and tested to estimate their feasibility, potential impacts, and user/provider reaction.

The following benefits arise from planned use of expert contractor support:

- Corporate memory and centralized documentation and data for system adjustments and tailored responses to user/provider inquiries

- Accurate reporting/documentation of system needs and viewpoints of both users and providers

- Objectivity in the conduct of special studies or further analysis and evaluation of recommendations

- Responsiveness and timely accomplishment of tasks

Intangible costs of the NAR are largely limited to the value of those forgone opportunities for application of time and material resources to other projects that have been instead committed to the NAR. Based on a review of major projects or programs currently underway or planned at FAA, resources committed to the NAR are not hampering implementation of any other major project or program.

MEASUREMENT APPROACH

The measurement of benefits and costs directly, especially of items such as efficiency, is not in all cases a straightforward undertaking. For some benefits and costs substitute measures must be found which can more readily be expressed in quantitative terms and aggregated with other, direct benefit and cost measurements to produce overall benefit-to-cost ratios for NAR enhancement areas.

As the first step in this process, the NAR recommendations were grouped into identifiable and homogeneous sets. The System Area/Enhancement Area classification in the *NAR Implementation Plan* has been used for this purpose. This classification contains the Model B/Airport Radar Service Area (ARSA), Air Route Traffic Control Center (ARTCC) Resectorization, and the Random Routes aspect of the RNAV Integration Enhancement Areas treated in this report. Each of these activities is the culmination of a NAR-related activity or set of recommendations. Although this grouping basis provides meaningful sets of recommendations, it should be noted that, in several cases, recommendations have fallen into more than one enhancement area; thus, measurement of costs on an enhancement area basis—rather than on a recommendation-by-recommendation basis—will lead to some overestimation of costs because of the double counting that must occur. The degree to which double counting occurs is not currently considered large and is not highlighted in this report.

The next step in the evaluation of benefits and costs is the identification and listing of the effects of each identifiable project that may evolve out of each enhancement area. This process of identification proceeds at the same time as units of measurement are identified. The exact definition of effects depends upon the chosen measurement unit and *vice versa*. This process of repeating steps is continued until a satisfactory and complete representation of benefits and costs is achieved for each enhancement area. For instance, though Model B/ARSA airspace might contribute significantly to increased user satisfaction (for those currently using Terminal Radar Service Areas (TRSAs)), user 'satisfaction' might best be measured in terms of reduced delays in traversing such areas, better information on traffic (reduced hazards or reduced separation requirements), and other quantifiable concepts rather than 'satisfaction'.

An additional determination required at this stage is that of the appropriate time period over which benefit and cost streams should be assessed. This depends in part on the *NAR Implementation Plan*,[6] and the anticipated timing-related system improvements identified in the *NAS Plan*, both of which provide indicators of appropriate enhancement area implementation timing.

Once effects are identified, classified as benefits or costs, and have dollar estimates assigned to them, aggregation of benefits and costs by Enhancement Area by year proceeds. Once this aggregation is done, a discount factor is applied to each year's benefits and costs (assuming 1983 as the current year) based on the Office of Management and Budget, OMB Circular A-94, suggested ten percent per year discount rate.

Following application of discount factors, the total present value of benefits and costs for each enhancement area is determined and is used to generate a benefit-cost ratio for that enhancement area. Figure 2 provides a schematic diagram of the process used to develop these measures and perform the analysis.

This analytic methodology is applied in this report by developing quantitative scenarios, and estimates of the benefits and costs, for ARSA implementation, ARTCC Resectorization, and the Random Routes aspect of RNAV Integration.

TASK GROUP MEETINGS

As a preliminary matter, each enhancement area involves, as a cost, the occurrence of task group

[6] *Op. cit., Implementation Plan*. See timing charts for each Enhancement Area.

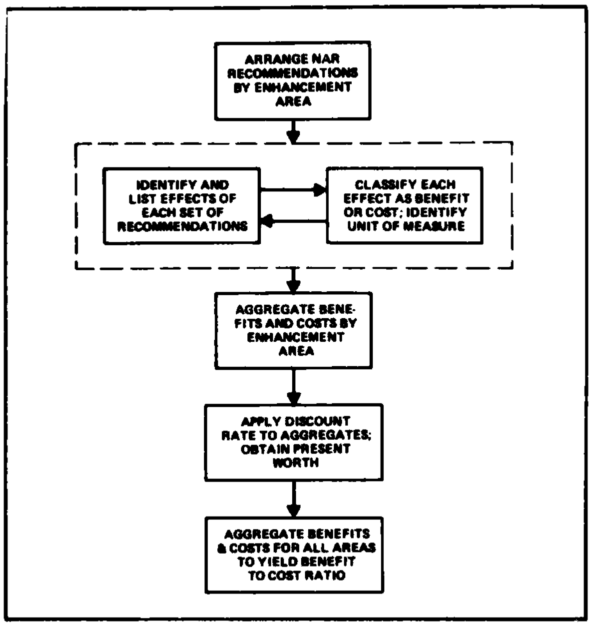


Figure 2. General Methodological Approach to Analysis of NAR Benefits and Costs

meetings. ARTCC Resectorization does not include these costs because its costs were incurred prior to the advent of the NAR task group meetings. Because the costs of those meetings will generally be a relatively small percentage of overall enhancement area costs, a representative average has been developed for the costs of a single task group meeting. These costs, shown in Figure 3, incorporate estimates of the labor and travel expenses for each category of organization and cover the entire task group meeting process from initial planning through staff study, including briefings, presentations and disposition of recommendations that may be associated with the meeting's subject matter. In addition, overhead costs, not specifically chargeable to task group meetings are included in this overall average costs of task group meetings.

FAA costs incorporate labor and travel associated with pre-meeting materials preparation, conferences with prospective task group chairmen and technical support personnel, actual task group meeting activities, and a variety of post-meeting documentation.

National Airspace Review Advisory Committee (NARAC) member costs include estimates of pre-meeting reviews of Advance Information Packages (AIPs), other preparation for task group meetings, participation during meetings, correspondence with associated membership following meetings, and review of post-meeting reports.

Technical support provided by Engineering and Economics Research, Inc., includes preparation of all materials used before and during task group meetings, preparation of daily summary minutes, preparation of all staff studies, and other post-meeting technical support which includes classifying recommendations, review and correction of staff studies, entry of new recommendations into the automated tracking system and oversight of enhancement areas implementation.

Related NAR Staff activities includes all costs that are overhead to task group meetings including travel, briefings, and presentations supporting the NAR Program and process generally.

FAA	$21,500
NARAC MEMBERS	21,500
TECHNICAL SUPPORT	45,300
RELATED NAR STAFF ACTIVITIES	6,000
TOTAL	$94,300

FIGURE 3. NAR PROGRAM AND TASK GROUP MEETING COSTS (1983 DOLLARS)*

*SEE APPENDIX FOR DETAILS

Figure 3. NAR Program and Task Group Meeting Costs (1983 Dollars)

Where the recommendations for a given enhancement area indicate that several task group meetings have contributed to the evolution of that area, a judgment has been made as to the aggregate number of task group meetings associated with each. In addition, this approach allows greater facility in charging partial task group meeting costs to one or more enhancement areas.

CHAPTER 3
AIRPORT RADAR SERVICE AREA (ARSA)

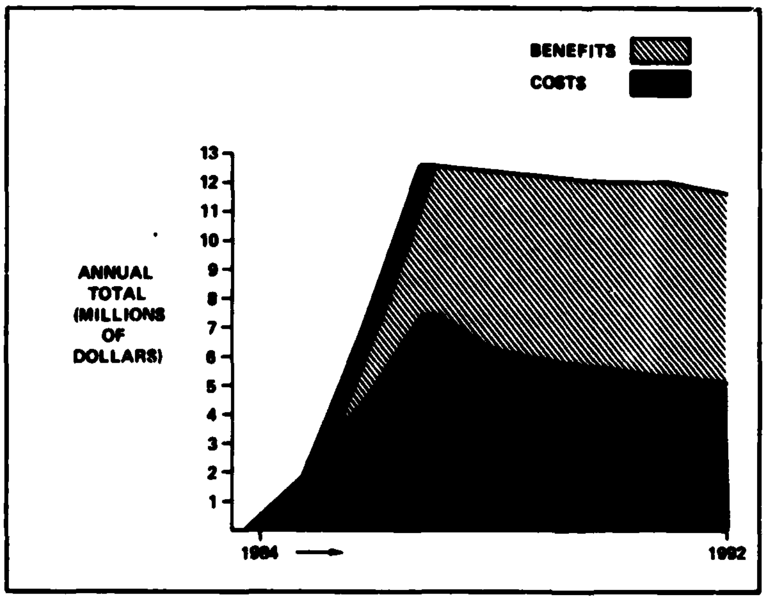
SUMMARY

The ARSA concept involves restructuring the airspace around some airports currently designated as Terminal Radar Service Areas (TRSAs). The concept, developed during NAR Task Group 1-2.2, is now undergoing operational confirmation at two sites (Columbus, Ohio, and Austin, Texas).

The scenario used here assumes that the ARSA concept will be applied, over time, to 139 current TRSA sites and that its effects will last until 1992. Benefits examined include a reduction in mid-air collisions (MACs) and a reduction in delays experienced by VFR aircraft, during off-peak hours, due to the reduced separation minimums in ARSA airspace versus that in TRSAs. Costs include delay increases experienced by VFR aircraft in entering ARSA airspace (due to the new two-way radio communications requirement), those experienced by all aircraft (during peak hours) due to arrival sequencing, and those experienced by VFR aircraft prior to departure as a result of the ARSA departure clearance requirement.

Total estimated benefits and costs are presented in Figure 4, both on an annual basis and in the aggregate. The ARSA benefit-cost ratio is estimated to be 1.92 to 1.00 based on these assumptions.

An intangible benefit arising from the ARSA concept is the clarification of pilot and controller responsibilities and, probably, easing of pilot education (especially among student pilots) due to the simplicity of the concept.



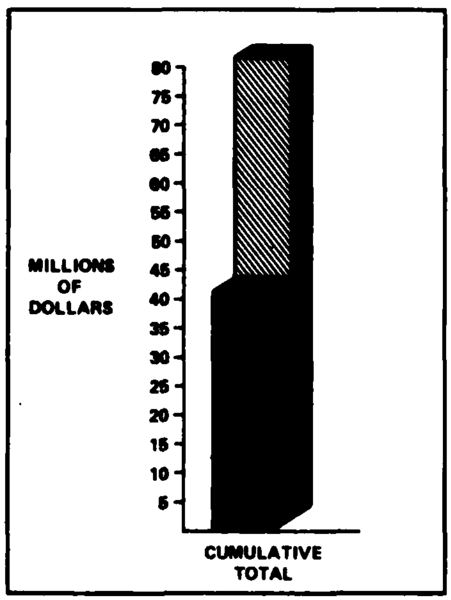


Figure 4. Summary of Annual and Overall ARSA Benefits and Costs (Discounted 1983 Dollars)

INTRODUCTION

Implementation of the ARSA concept involves the restructuring of airspace around many airports currently designated as Terminal Radar Service Areas (TRSAs). Instead of the current TRSA voluntary participation, aircraft will be required to maintain two-way radio contact with ATC while within the ARSA core area (within five nautical miles of the airport tower, from the surface to 4000 feet height above airport (HAA), and from five to ten nautical miles out while between 1200 and 4000 feet HAA). All aircraft operators arriving at an ARSA airport are required to participate in arrival sequencing, but VFR separation minimums are reduced within the airspace core. All aircraft departing from ARSA airports are required to obtain a departure clearance.

The ARSA concept was primarily developed during NAR Task Group 1-2.2 and is currently undergoing an operational confirmation at two sites (Columbus, Ohio, and Austin, Texas) prior to expanded application. In support of this operational confirmation, the Office of Aviation Policy and Plans (APO) has prepared an economic analysis for the two sites involved.[7] The benefit-cost analysis presented here is based on a modified extrapolation of this APO work.

The APO study identified the principal benefits from ARSAs as being a reduction in midair collisions (MACs) and a decreased VFR separation standard which will lead to reduced VFR delays in non-peak hour arrivals. The study identified the principal costs as including training and education, departure delays for currently non-participating VFR aircraft, peak hour arrival sequencing delays, and delays due to the ARSA mandatory communications requirement. The primary source measures for the APO study were controller interviews (for delay estimates) at the operational confirmation sites and an APO-developed regression analysis linking ARSA-avertable MACs to traffic levels at TRSA sites.

The delay measures used in the APO study have been weighted and applied to all ARSA candidate sites in this study, and the regression analysis relationship has been applied directly to projected traffic volumes at all ARSA candidates to yield aggregated benefits and costs.

Following performance and evaluation of the ARSA concept at Columbus, Ohio, and Austin, Texas, it is assumed that FAA will proceed to implement ARSAs at all existing TRSAs. For purposes of scenario definition, this study assumes that 28 will be implemented in 1985, 45 more in 1986, and a final 64 in 1987. Overall, it is assumed that 139 ARSAs will be in operation by mid-1987, and that their operational effects will be largely expended by 1992. This limitation to 1992 is based on the expectation that other activities, improvements, and airspace or procedural changes will occur between now and 1992 due to other NAR recommendations and *NAS Plan* implementation. These actions are expected to substantially improve aircraft tracking and collision avoidance capabilities. As a result, it is felt that no ARSA-dependent benefits will be distinguishable after 1992. The benefit and cost stream is therefore stopped in 1992 and a benefit to cost ratio determined for that date.

BENEFITS

As indicated in the APO study, the primary, measurable benefits from implementing ARSAs are expected to be a reduction in mid-air collisions (MACs) and an operating cost savings from reduced separation minimums.

[7] U.S. Department of Transportation, Federal Aviation Administration, *Regulatory Evaluation of Notice of Proposed Rulemaking to Implement an Airport Radar Service Area at Columbus, Ohio, and Austin, Texas*, Office of Aviation Policy and Plans, Regulatory Analysis Branch, July 13, 1983. (Hereinafter *Regulatory Analysis*).

Avertable MACs

The APO study (hereinafter "regulatory analysis") provides the following description of its assessment of ARSA-avertable MACs.[8]

"The FAA conducted an extensive review of MAC accidents that occurred during the period from 1978 to 1982. Data were derived from National Transportation Safety Board (NTSB) accident reports and the FAA Accident/Incident Data System. The FAA considered only those MAC accidents which occurred within proposed ARSA airspace at the 136 airports (as of July, 1983) which employ TRSA services and in which at least one operator was not communicating with ATC or the midair occurred because one operator did not receive arrival sequencing." The FAA projected the number of MACs that would have occurred in the proposed ARSA airspace over the five-year period.

"A regression analysis was developed which provides an analytic expression of the average midair collisions in proposed ARSA airspace per airport providing TRSA services from 1978 to 1982, as a function of average aircraft operations per airport, on the basis of calendar year 1982 operations . . . The five year collision estimator is in the form $C = an^b$ where:

- 'C' is the average number of MACs occurring in proposed ARSA airspace per TRSA airport over the period of January, 1978, to December, 1982;
- 'a' and 'b' are the coefficients which yielded the least error between the actual and estimated number of collisions;
- 'n' is the average number of aircraft operations per TRSA airport in 1982 in units of 100,000 had the ARSA been implemented (local, itinerant, plus an additional average estimate of 10% of local and itinerant to account for additional operations handled by ATC in an ARSA)." Figure 5 provides a depiction of average operations per ARSA assumed for the analysis presented in this report. This average appears to drop after 1984 and then rise in later years because the first year average is based on Austin and Columbus and both have well above average annual operations. The inclusion of more candidate sites in later years lowers the average which then rises consistent with the five percent traffic growth assumed for this analysis.

"When scaled to an *annual* basis by a scaling factor of 4.5 to account for activity growth over the five year period, the ARSA collision formula becomes:

$$C = \frac{0.12\, n^{1.80}}{4.5} = .027n^{1.80}$$

* * *

The costs of a MAC include damage to the aircraft, the value of lives lost and the cost of injuries. The average weighted cost per general aviation MAC accident in 1983 dollars is \$1,644,000."[9] This dollar amount is derived by considering such factors as different types of GA aircraft, average numbers of occupants that fly on these aircraft, probabilities that relevant costs will be incurred, and distribution of hours flown by aircraft type.

Utilizing the equation developed by APO, 1982 air traffic activity at TRSAs,[10] and the assumption of an annual five percent increase in traffic

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[8] *Op. cit., Regulatory Analysis*, pp. 8-11.

[9] *Op. cit., Regulatory Analysis*, pg. 26, Table 2.

[10] See U.S. Department of Transportation, Federal Aviation Administration, *Airmens Information Manual*, Paragraph 166, December 12, 1982, pg. C4-S1-11, and U.S. Department of Transportation, Federal Aviation Administration, *FAA Air Traffic Activity, September, 1982*, pp. 16-45.

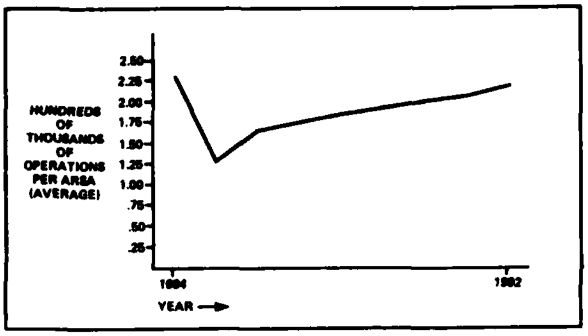

Figure 5. Average Operations Per ARSA by Year

activity at potential[11] ARSA sites, an average value for avertable MACs per ARSA site per year was developed. The discrepancy between the 4.5 percent traffic growth factor used to estimate ARSA-related MAC reductions and the five percent used for future activity growth arises from the fact that the actual growth trend at the surveyed potential ARSA sites was 4.5 percent for 1978-1982 whereas the five percent future growth factor is a projection. Based on this analysis and the scenario described above, the total MAC reduction anticipated from an ARSA program is 83. Figure 6 depicts the cumulative total of averted MACs projected for the ARSA program on a year by year basis.

Utilizing the annual MAC reduction figures and the APO-developed MAC cost of $1,664,000,

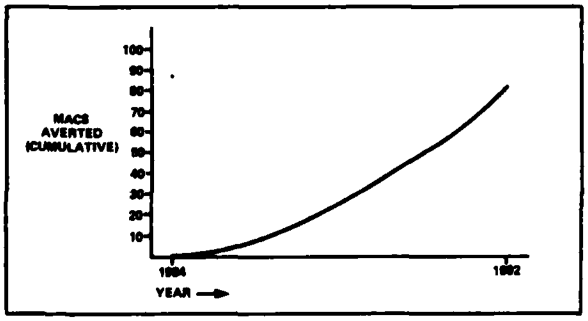

Figure 6. Cumulative Reduction in MACs at ARSAs

MAC reduction-related dollar benefits have been derived. These benefits are displayed in Figure 7.

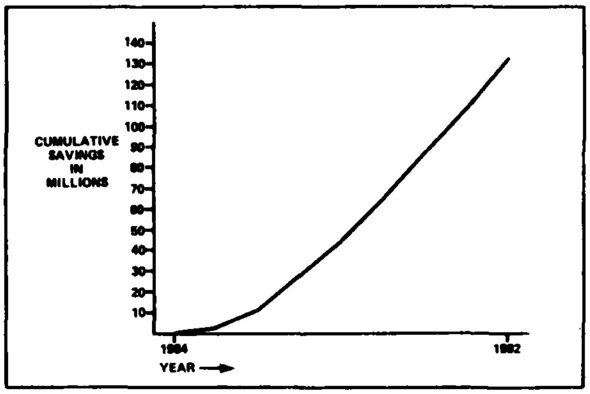

Figure 7. Cumulative Dollar Savings from MAC Reduction (Undiscounted)

Reduced VFR Separation Minima

The regulatory analysis described benefits from reduced VFR separation minima as follows:[12]

"Certain VFR operators should experience some savings in arrival time as a result of the proposed reduced separation minimums (1 1/2 miles to approximately 400 ft. horizontally)." Based on estimates by local ATC personnel at the two operational confirmation sites, this proposed rule would, using a straight-line average,[13] save 60 operators one minute per operation, per day, three days per week. If this estimate is applied at each ARSA site, then 9360 flights per year per ARSA site would benefit by one minute of reduced delay. Because the program begins with only two sites and then increases to 30, then 75, and finally 139, the delay reduction benefit appears to decrease

[11] *Op. cit., Regulatory Analysis*, pp. 11-12.

[12] *Ibid.*

[13] Estimates at the two sites differ slightly. For purposes of this analysis, a straight-line average is applied for all potential ARSA sites.

dramatically in the first few years and then flatten out in later years. Later year increases in the benefit arise from increased traffic activity alone. This is shown in Figure 8.

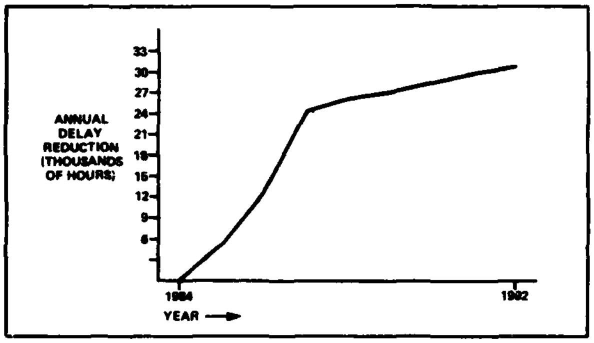

Figure 8. Reduced Delay in ARSAs (Due to Reduced VFR Separation Minimums)

APO estimates that the average variable operating cost (VOC) (private pilot/crew time, fuel and oil, and maintenance) of a general aviation (GA) aircraft is $89.94 per hour.[14] Based on this figure, total hours saved, and the five percent traffic increase already noted, total VFR separation reduction savings were developed and are depicted in Figure 9.

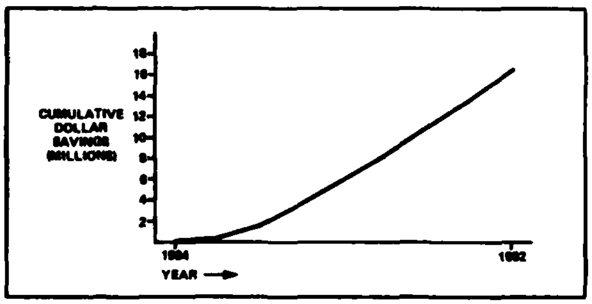

Figure 9. Cost Savings from Reduced Delays in ARSAs (Undiscounted)

Total ARSA Program benefits were derived by combining the two cost savings just described. This total was then discounted in conformance with OMB Circular A-94 to yield a present worth in 1983 dollars. Based on this methodology, the total discounted value of ARSA program cost savings is $84.5 million. This is depicted in Figure 10.

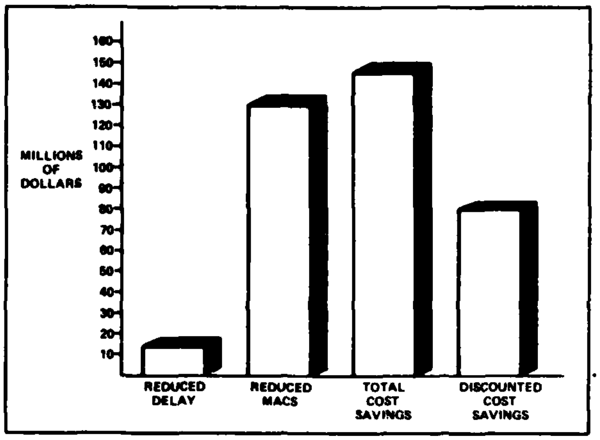

Figure 10. Total Discounted ARSA Benefits (1983 Dollars)

COSTS

The costs associated with implementation and operation of ARSAs fall primarily into five categories.

- Costs incurred in development of the NAR Program, and in particular, arrangement and convening of Task Group 1-2.2, which developed the ARSA concept and parts of other task group sessions that made limited inputs to the concept.
- VFR departure delays expected to affect certain types of general aviation operators not currently participating in TRSAs.
- VFR arrival sequencing delays occurring during peak hours as a result of ARSA mandatory sequencing requirements.

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[14] *Ibid*. And see U.S. Department of Transportation, Federal Aviation Administration, *Economic Values For Evaluation of Federal Aviation Administration Investment and Regulatory Programs*, Report No. FAA-APO-81-3, September, 1981.

- VFR delays occurring as a result of the requirement for ATC permission to enter an ARSA.

- Federal government costs associated with the initial operational confirmation and training/education at each ARSA site.

Each of these cost elements is detailed below and in the accompanying figures. Total discounted costs for the ARSA Program are estimated to be $43.9 million.

The APO study describes the following costs.[15]

Task Group Meetings

In addition to the entire session of Task Group 1-2.2, one-half of the sessions of Task Groups 1-2.3 and 1-2.4 concentrated on issues associated with this concept. As a result the total task group meeting related costs of the ARSA concept are $188,658.

VFR Departure Delay

"On the basis of previously provided Stage III TRSA services, it has been estimated by air traffic controllers that 33 percent of operators departing VFR would not participate in the full ARSA departure services if voluntary.[16] FAR Part 91.87 already requires that operators departing an airport traffic area maintain two-way communication with ATC. The new additional requirement imposed by the ARSA is that these VFR operators would be required to contact clearance delivery for a departure frequency and departure code. The time for an operator to contact clearance delivery is estimated to be 1 minute. This would not impact IFR operators because they are already required to contact clearance delivery." It is estimated by local ATC personnel at the two operational confirmation sites that, based on a straight line average,[17] 66 VFR departures per day (33 percent of 200 daily VFR departures), per ARSA will experience this one minute delay. Figure 11 displays the hours of delay that will be experienced due to departure clearance requirements as well as for arrival sequencing and ARSA entry requirements. The delays shown are both cumulative and additive, with each type of delay represented by the space between the lines bounding its label.

"FAA assumes that these are mostly general aviation operators and, on the basis of local ATC personnel estimates, that the mix of aircraft flown by these operators is 50% - 30% - 20% for single engine piston (SEP), multi-engine piston (MEP) and turboprop (TP), respectively. Furthermore, FAA estimates the value of time to operators of SEP, MEP and TP aircraft in 1983 dollars is $21.56, $40.66 and $179.82 per hour, respectively. These estimates are based on the assumption that operators of SEP aircraft are private pilots, while operators of MEP and TP aircraft are salaried crew pilots. FAA believes that assuming the pilots of MEP and TP aircraft are salaried crewmembers overstates the actual cost impact. On the basis of these values of time cost factors and mix of aircraft flown by these operators, the average weighted GA operator value of time per hour is $58.95."[18] Figure 12 presents an overall estimate of cumulative delay costs based on total hours and operator value per hour.

VFR Arrival Sequencing Delay/Peak Hours

"Certain VFR operators could experience some delay during ATC peak hour operations resulting from mandatory arrival sequencing requirements. While these operators would benefit

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[15] *Op. cit., Regulatory Analysis*, pp. 15-21.

[16] Thirty-three percent is an average of the figures for Austin and Columbus.

[17] See footnote 13.

[18] *Op. cit., Regulatory Analysis.*

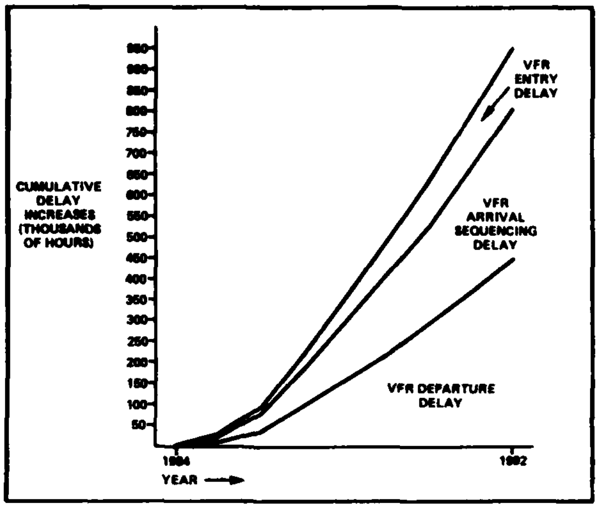

Figure 11. Cumulative Delay Increases Due to ARSAs

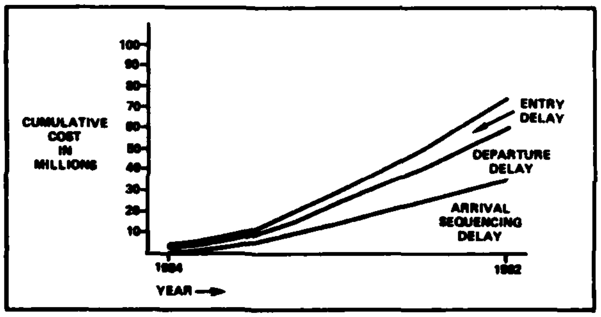

Figure 12. Cumulative Cost of ARSA Delay Increases (Undiscounted)

from ARSA reduced separation minimums with time savings of approximately one minute, they would experience delays of approximately 2.5 minutes or a marginal arrival sequencing delay of 1.5 minutes per operation." This requirement, based on estimates by local ATC personnel at the two operational confirmation sites, would on the average[19] impact 60 operations per day, four days per week.[20] Figures 11 and 12 (above) provide a summary of these delays and costs.

VFR Delay Encountered to Enter the ARSA

"Certain VFR operators could experience some delay as a result of being denied immediate entrance into the ARSA when ATC handling of arriving traffic is at capacity." Estimates by local ATC personnel at the two operational confirmation sites indicate that, on the average,[21] 50 operations per week will experience an average three minute delay before they are given ATC approval to enter an ARSA.[22] These delays and costs are also shown in Figures 11 and 12.

FAA Education, Training Program and Administration Costs

The FAA has undertaken an operational confirmation of the ARSA concept at two sites. Costs for supporting this activity in the form of study design, data collection, and evaluation are expected to total approximately $500,000.

In addition, the FAA will incur initial one-time only costs to train local FAA facility managers' staffs and conduct meetings with local airmen to explain the ARSA concept. The initial nonrecurring costs relating to this requirement include personnel costs, travel, per diem, town hall rental, letters to airmen, bulletins, etc., and are approximately $20,000.[23] Overall costs for this training and education activity are presented in Figure 13.

A summary of ARSA Program costs is presented in Figure 14.

Overall, implementation of the ARSA concept would generate an estimated $84.5 million in benefits and $43.9 million in costs through 1992. Based on these estimates, the benefit-to-cost ratio for the ARSA program is estimated to be 1.92 to 1.00 and is depicted in Figure 15.

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[19] See footnote 13.

[20] *Op. cit., Regulatory Analysis.*

[21] See footnote 13.

[22] *Op. cit., Regulatory Analysis.*,

[23] *Op. cit., Regulatory Analysis*, pg. 20.

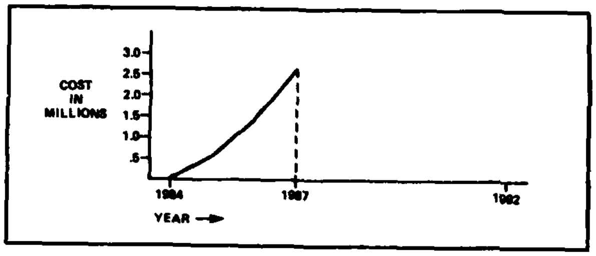

Figure 13. Cumulative Costs of Training and Education (Undiscounted)

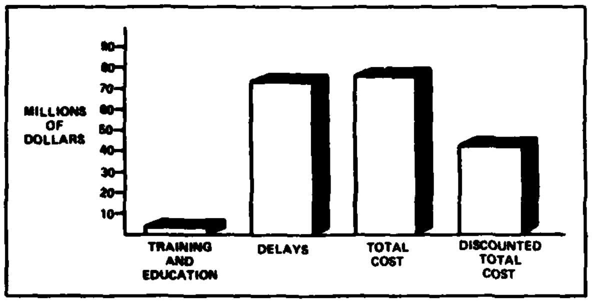

Figure 14. Total Discounted ARSA Costs (1983 Dollars)

INTANGIBLES

An intangible benefit arising from the ARSA concept is the clarification of pilot and controller responsibilities and, probably, easing of pilot education (especially among student pilots) due to the simplicity of the concept.

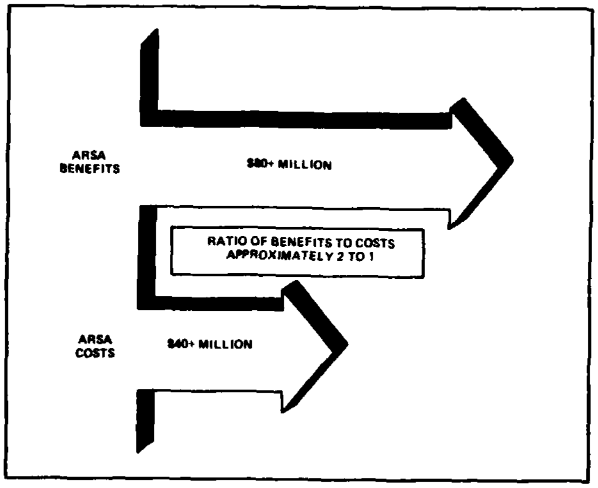

Figure 15. Benefit-Cost Ratio of ARSA Enhancement Area

CHAPTER 4
ARTCC RESECTORIZATION

SUMMARY

Among the earliest planned activities of the NAR was an examination of a program to realign ARTCC sector boundaries to more closely reflect traffic flows, eliminate or reduce conflicts, enhance current automation capabilities, level controller workload, and improve system capacity. This Resectorization Program began prior to the NAR, however, due to the controllers' strike. Its implementation is now virtually complete.

Quantifiable benefits from the program are primarily labor savings arising from a reduction from 721 to 586 sectors (135 sectors eliminated). The sector reduction translates into $55 million per year in avoided controller salaries. This labor savings can be considered an annual savings as long as other events do not occur which would reduce required controller numbers regardless of resectorization. A general reduction in required controllers cannot be expected before some form of the Automated En Route ATC (AERA) concept is implemented. This is not expected before 1990. In addition, a one-time equipment cost avoidance of $70 million is anticipated.

Primary quantifiable costs for the program include program development, labor hours for implementation, travel, and equipment. Most of these costs have already been incurred and total approximately $12 million.

The estimated benefits and costs of the Resectorization Program are displayed in Figure 16. The anticipated benefit-cost ratio of the program is estimated to be 25.25 to 1.00.

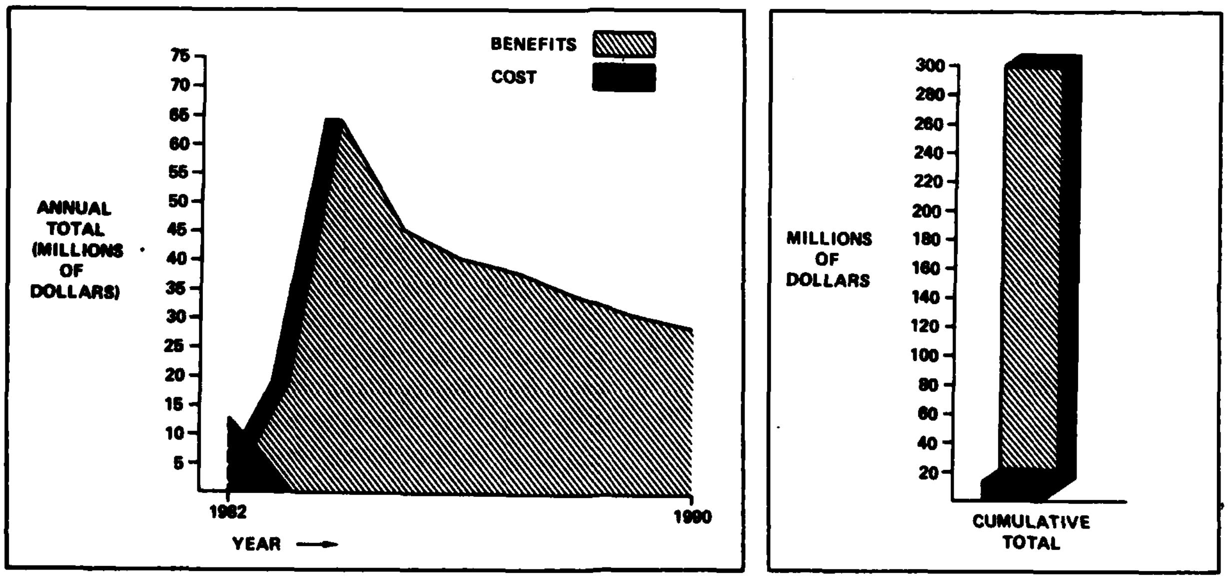

Figure 16. Summary of ARTCC Resectorization Benefits and Costs by Year and Overall (Discounted 1983 Dollars)

Intangible benefits from resectorization include:

- an increase in overall system effectiveness arising from sector boundary realignments that follow major traffic flows more closely;
- laying groundwork for increased random area navigation operations in the NAS;
- an improvement in the balance of work placed on different versions of the NAS 9020 computers which is enhancing the working life of the overall computer system;
- more efficient metered traffic flows in terminal areas;
- encouragement of en route metering through realignments that recognize an approximate 200 nautical mile radius around major airports;
- encouragement of more fuel efficient descents through realignments that recognize an approximate 135 nautical mile radius around major airports; and
- increased en route safety and efficiency due to removal of sector boundaries from existing traffic conflict points.

INTRODUCTION

One of the initial objectives of the National Airspace Review was an examination of a program to realign ARTCC sector boundaries to more closely reflect traffic flows, eliminate or reduce conflicts, enhance current automation capabilities, level controller workload from sector-to-sector, and improve system capacity.

While the resectorization program was intended to be the subject of the first task group meetings, its implementation was forced to begin prior to the NAR program due to the severe shortage of controllers caused by the 1981 strike. Implementation of the resectorization program thus began in mid-1982 and is now virtually complete. To date, all of the program's sector reduction and workload objectives have been met. One-hundred thirty-five sectors (out of more than 720 originally) have been eliminated. This has in turn allowed for the retirement of much of the expensive equipment (Plan View Displays [PVDs]) needed to support controller activities in each eliminated sector. There has been a major equipment cost avoidance even though each ARTCC has retained up to 10 extra sectors as reserves, and sector boundaries have been realigned to accommodate a 30 percent traffic growth factor.

Most of the Resectorization Program's costs have already been incurred. Its benefits, however, can be expected to continue for several more years until some form of the Automated En Route ATC program matures and is implemented. Assuming that this will occur in the early 1990's, the Resectorization Program is assumed to cease to produce benefits and incur costs in 1990.

BENEFITS

The primary quantifiable benefits of the ARTCC Resectorization Program are costs avoided in the form of reduced labor requirements (fewer controllers) and reduced equipment (fewer PVDs).[24] Thus, for each of the 135 eliminated sectors, the need for an average of 11.7 controllers, at $35,000 per year, is eliminated. This totals $55,282,500 per year. Based on the assumption that these labor costs would continue to be incurred in the future unless the Resectorization Program had been implemented, they are assumed to be avoided annually until program termination in 1990.

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[24] U.S. Department of Transportation, Federal Aviation Administration, Air Traffic Service, AAT-300, memorandum summarizing estimated benefits and costs of Resectorization Program; May 27, 1982. (Hereinafter "AAT-300 memo".)

In addition, for each of the 135 sectors eliminated, one PVD has been assumed to be eliminated. Eliminated spares are ignored in this analysis because of the additional sectors each center has retained. Thus, 135 PVDs, at $152,200 per PVD, are eliminated for a total equipment cost avoidance of $89,650,125 (approximately $70 million when discounted). Because the program has been phased in during the past year, however, and will not fully realize this avoided cost immediately, only 25 percent of these avoided equipment costs are assigned to 1983, with the remaining 75 percent assigned to 1984. These costs have not been spread over the life of the program because, prior to resectorization, there was a recognized need to replace many of these units. Thus, avoided costs occur earlier in the program than they otherwise might.

Total discounted benefits are thus estimated to be $303 million. These benefits are illustrated in Figure 17.

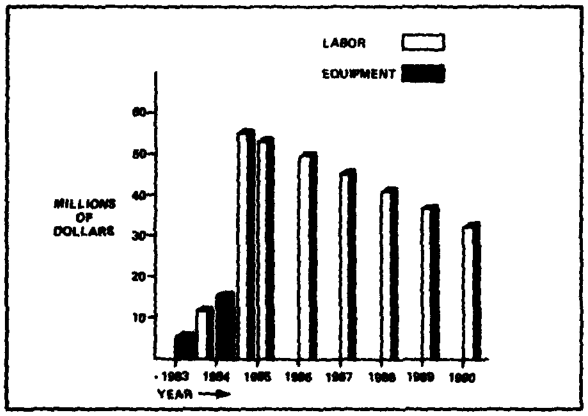

Figure 17. Total Discounted ARTCC Resectorization Benefits by Year (1983 Dollars)

COSTS

The primary costs[25] associated with this program are one-time-only and cover the sector redesign, briefings, multi-level reviews and implementation aspects of the program. Program development, sector redesign, and national and regional briefings and reviews were estimated by Headquarters and regional ATC personnel to total 1,103 man-days. Implementation was further estimated, by the lead Resectorization Program ARTCC, to require from 44,000 to 66,000 man-days total. This wide variation is due to unpredictable differences in implementation workload from ARTCC to ARTCC. Total travel, funded through the NAR budget, was estimated at $74,000. Equipment costs were estimated on a 1983 and 1984 basis at 25 percent/75 percent, similar to the treatment of benefits. Preparation of new video maps was estimated at $500 per ARTCC and sector relocation or reallocation at $8,000 per sector for each of the 135 sectors.

Total discounted costs are thus estimated to be from $10.3 million to $14.1 million with an average of about $12 million. These costs are illustrated in Figure 18.

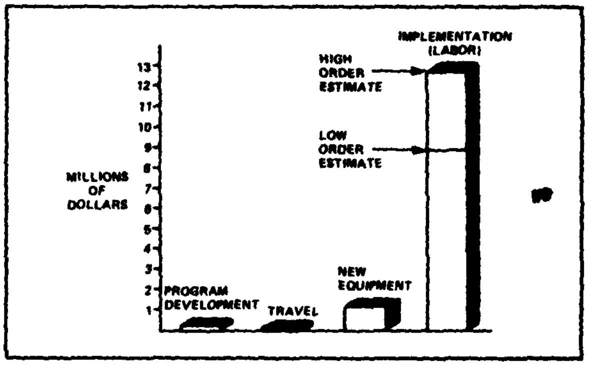

Figure 18. Total Discounted ARTCC Resectorization Costs (1983 Dollars)

The benefit-to-cost ratio for ARTCC Resectorization is estimated to be 25.25 to 1.00, assuming actual costs fall in the mid-range of estimates (i.e., $12 million). This ratio is illustrated in Figure 19.

[25] *Ibid.*

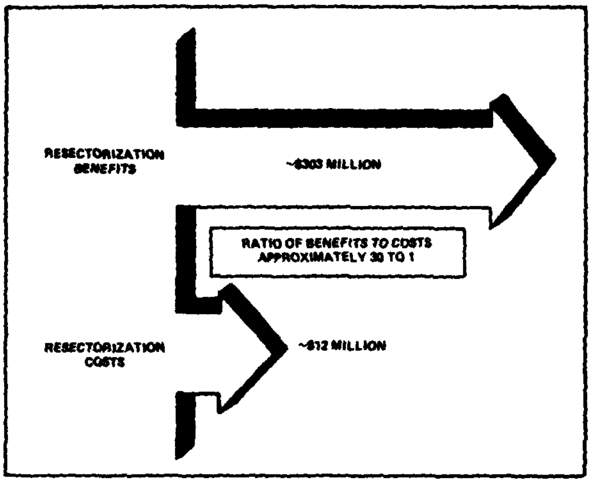

Figure 19. Benefit-Cost Ratio of ARTCC Resectorization Enhancement Area

INTANGIBLES

The Resectorization Program was designed to work at more than one level and to respond to several, sometimes conflicting system requirements. In particular, overall system effectiveness is expected to increase as a result of sector boundary realignments that more accurately reflect major traffic flows. Further intangible benefits are expected from an improved balance of computer workload assigned to different versions of the NAS 9020 computers. This should result in enhancing the useful life of the computer system. In addition to these immediate improvements, resectorization is intended to begin preparing the entire airspace system for the advent of increased area navigation (RNAV) operations. By reconceiving of the system with the presence of RNAV, en route metering, and other advanced automation, sectors were designed to recognize both an approximate 200 nautical mile and 135 nautical mile radius around major airports and were aligned to allow more efficient metered flows. Although runways constitute the ultimate limit on airport capacity, these design objectives have enhanced existing capacity to some degree.

The benefits anticipated from this program may go far beyond mere productivity gains, even though they may not be fully realized for several more years. The immediate analysis has concentrated on the more tangible, near term productivity gains.

CHAPTER 5

RNAV INTEGRATION: RANDOM ROUTES

SUMMARY

The Random Routes aspect of RNAV Integration is comprised of a set of activities directed toward enhancing pilot use of, and controller ability to accommodate, increased random area navigation in flight.

The primary benefit from undertaking such actions will be reduced fuel consumption. Based on fleet make-up, size, and an increasing rate of RNAV utilization, this reduction is estimated to total $1.547 billion in discounted 1983 dollar benefits for the 17-year period to 2000.

Costs include program development, controller and pilot training, and RNAV avionics. Together these costs are estimated to total $676 million in discounted 1983 dollars through 2000.

Figure 20 presents both annual and cumulative totals for RNAV Integration.

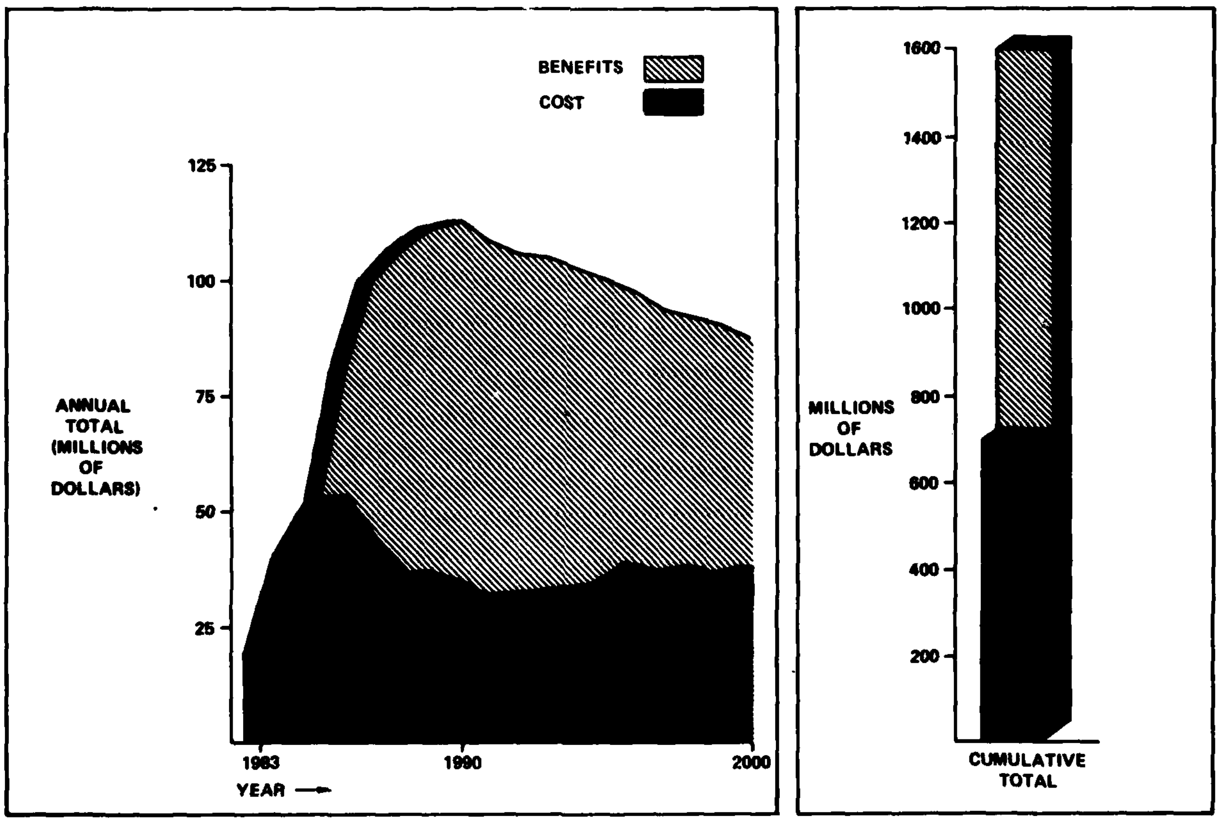

Figure 20. Summary of RNAV Integration Benefits and Costs by Year and Overall (Discounted 1983 Dollars)

The estimated benefit-cost ratio (low order) for this aspect of the Enhancement Area is 2.29 to 1.00.

Intangible benefits of RNAV Integration include an eventual reduction in airway and route inspection/maintenance due to reduced airways and routes in the NAS, and increased pilot positional awareness.

Intangible costs may include some additional effort by pilots, especially students, in order to utilize an airspace system which permits a choice among substantially different navigational methods.

INTRODUCTION

The random routes aspect of the RNAV Integration Enhancement Area is concerned generally with those actions which will lead to the expanded use by pilots of (and ATC capability to accommodate) random area navigation (RNAV) routings. The benefits of undertaking such actions were indicated in Operation Free Flight[26] and are primarily fuel consumption reductions. Costs, on the other hand, will encompass NAR recommendation formulation, program development, controller and pilot training, and RNAV avionics costs. Because no significant alternative to or burden on RNAV use is anticipated in the forseeable future, and *NAS Plan* navigation projections continue only to the year 2000,[27] the benefit and cost stream is taken to that year, beyond which no forecast is currently considered reasonable.

BENEFITS

Operation Free Flight suggested that fuel consumption reductions of 2-3 percent could be expected from random RNAV route utilization in the NAS.[28] Because the VOR/DME navigation system is to be maintained, thus assuring a mixed RNAV and VOR/DME operation of the NAS, a forecast of the future RNAV-equipped fleet and operational utilization of RNAV is required in order to estimate fuel consumption benefits. Figures 21 and 22, showing RNAV avionics equippage and utilization,[29] were developed[30] to estimate these benefits. These projections take into account two anticipated factors. Firstly, with the advent of the operational Global Positioning System (GPS) in 1988, there will be a new incentive for aircraft owners to acquire RNAV avionics, especially if equippage costs are reasonable. Furthermore, it is assumed that RNAV avionics standards will be fully developed and optimized for ATC system integration in the early 1990's (1993) and that this will provide an additional incentive.[31] These two events are represented by discontinuities in the figures. In addition, there are two values for (GA) equippage and utilization. These divergent values are presented because of the lack of a clear indication regarding the degree to which GA owners/operators will move to RNAV despite the fact that recent manufacturing trends seem to be placing more emphasis on lower cost RNAV avionics. (It can be assumed that, as costs for equipment drop relative to any inconvenience arising from not having such equipment, equippage and utilization will increase.)

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[26] U.S. Department of Transportation, Federal Aviation Administration, Air Traffic Procedures Division, *Operation Free Flight*, Final Report, Report No. FAA-AT-81-1, July 1, 1981.

[27] U.S. Department of Defense and Department of Transportation, *Federal Radionavigation Plan*, Vol. 1, "Radionavigation Plans and Policy," Report No. DOD-4650.4-P-1 and DOT-T3C-RSPA-81-12-1, March 1982, pp. I-24 to I-64.

[28] *Op. cit., Operation Free Flight*, pg. I-3.

[29] Number of RNAV hours flown divided by total operating hours.

[30] Estimates are based on Headquarters ATC personnel judgment of implementation effects.

[31] Headquarters navaids personnel judgment.

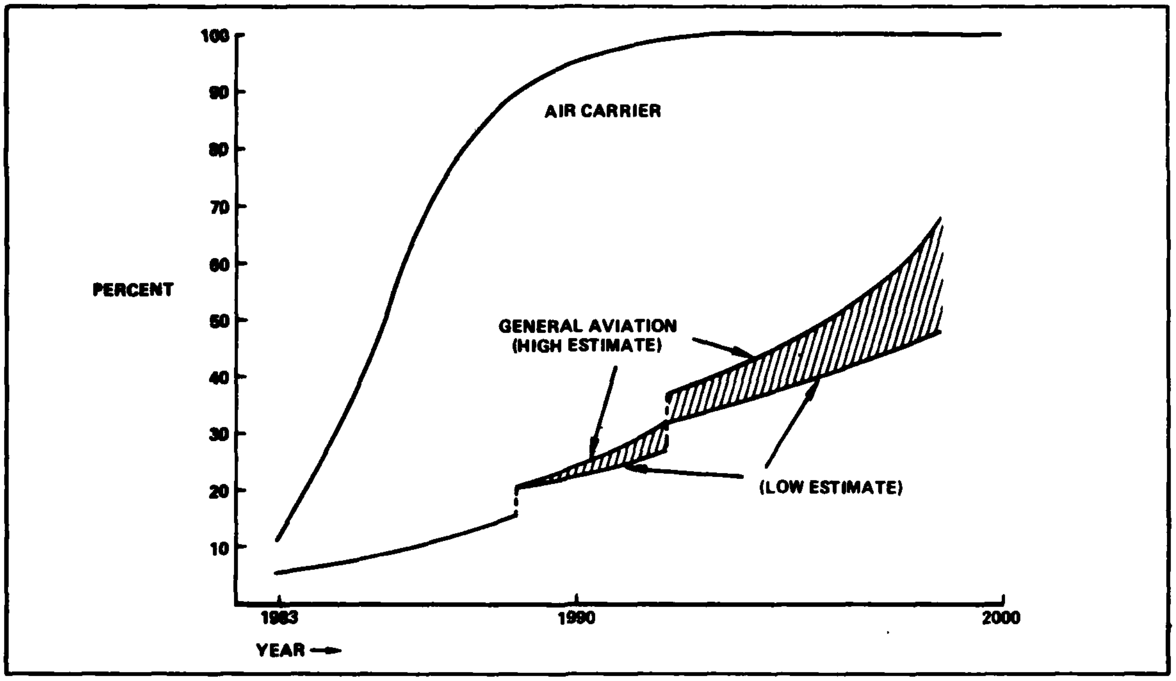

Figure 21. Estimated Cumulative RNAV Equippage Levels (by Aircraft Type)

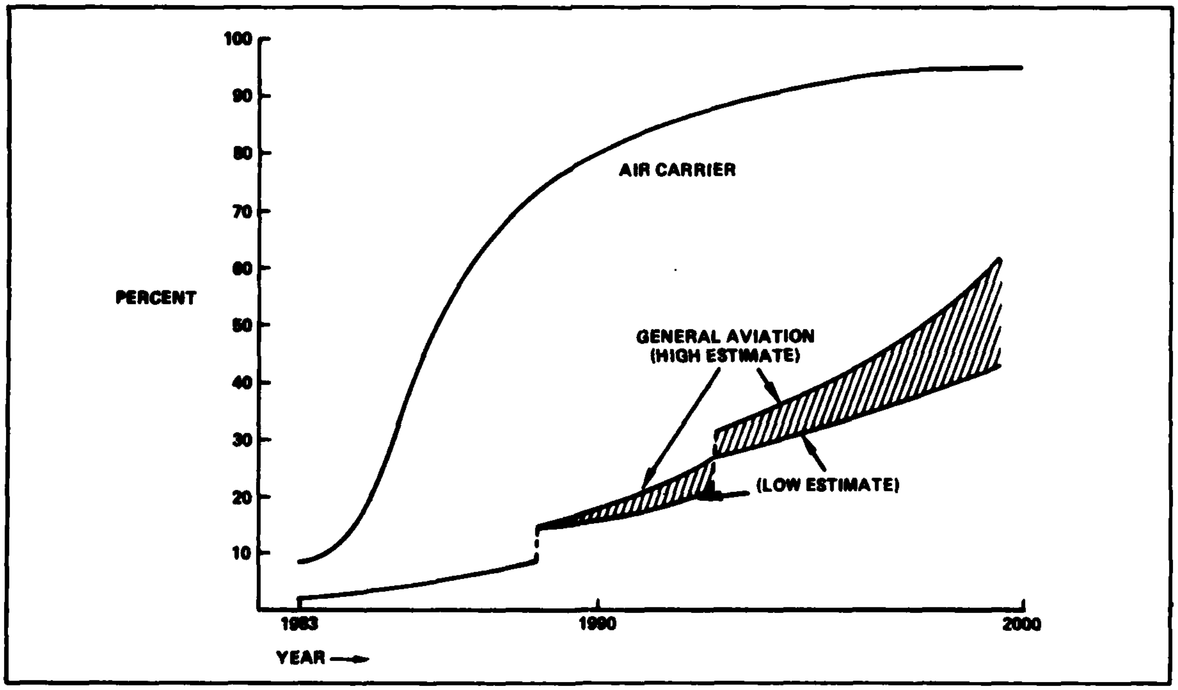

Figure 22. Estimated Cumulative Percent RNAV Navigation Utilization (by Aircraft Type)

RNAV fuel cost savings were calculated as follows. FAA 1982 Aviation Forecasts[32] were collected for air carrier and general aviation fuel consumption. For the period from 1995-2000, a straight line extrapolation (approximately 3.5 percent per year) of fuel consumption was assumed as depicted in Figure 23. There is a significant percentage of GA aircraft that uses jet fuel; however, virtually no aviation gasoline is used by air carriers. The difference in total civil fleet fuel consumption between jet fuel and aviation gasoline, therefore, provides some indication of the differences in consumption between air carriers and general aviation.

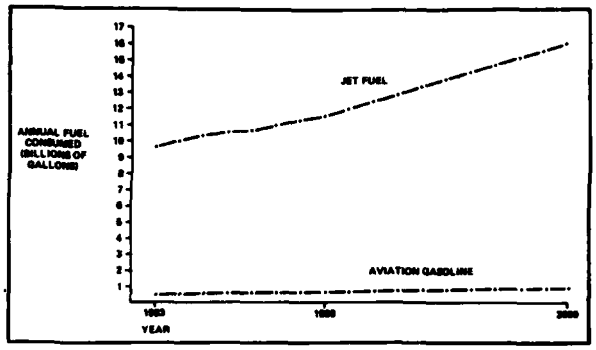

Figure 23. Estimated Total Fuel Consumption Per Year (by Fuel Type)

The percentages of utilization by year, by type of operation, were then applied to these forecast levels. An average of 2.5 percent fuel savings was then calculated, which in turn was multiplied by average air carrier fuel costs ($1 per gallon)[33] or GA fuel costs ($2.05 per gallon),[34] as appropriate, to yield total annual and aggregate fuel savings. Total discounted benefits were thus calculated to be between $1.52 and $1.55 billion dollars for the period 1983-2000. Figure 24 depicts these annual benefits.

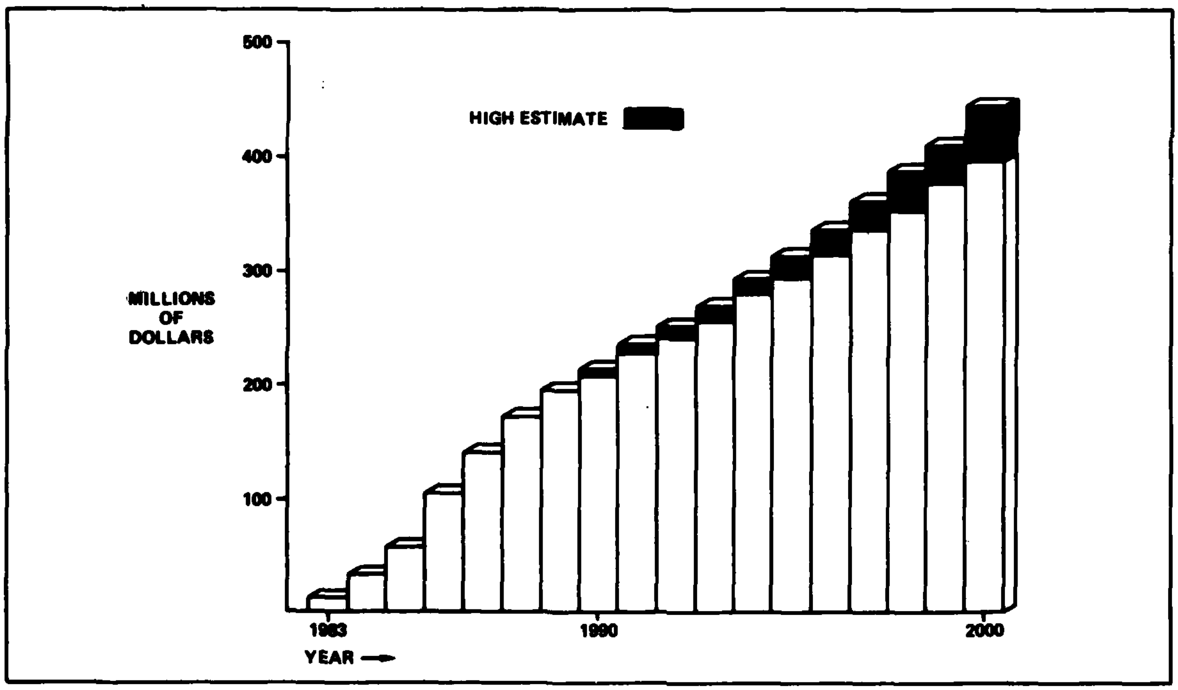

Figure 24. Total RNAV Integration Benefits by Year (Undiscounted 1983 Dollars)

[32] U.S. Department of Transportation Federal Aviation Administration, *FAA Aviation Forecasts, Fiscal Years 1983-1994*, Report No. FAA-APO-83-1, February 1983, pg. 54.

[33] *Ibid.*, pg. 21.

[34] *Ibid.*

COSTS

The cost elements[35] of Random Routes are described in more detail below.

NAR Recommendation Formulation/Program Development

NAR Task Group 1-3.1 developed the major recommendations which form this enhancement area. In addition to the task group meeting costs, FAA staff costs will be incurred in developing the ultimate program. These costs are estimated to total one hundred fifty thousand dollars.

Controller Training

FAA personnel costs will be incurred in order to enhance the RNAV segment in the current new controller curriculum (five additional hours are estimated) and to re-train a significant percentage of controllers (45 percent) now in the field.[36] These costs are estimated at approximately $30,000 per year throughout the program.

RNAV Avionics

The largest cost component associated with RNAV Integration is expected to be the costs borne by airspace system users to purchase the area navigation equipment necessary to allow random or direct RNAV operation. Costs in this category are based upon the equippage estimates noted above for air carrier and general aviation aircraft. The annual costs of RNAV avionics systems,[37] by aircraft type, are depicted in Figure 25. These costs are shown as an annual aggregation of general aviation, business jet, and air carrier acquisitions of RNAV

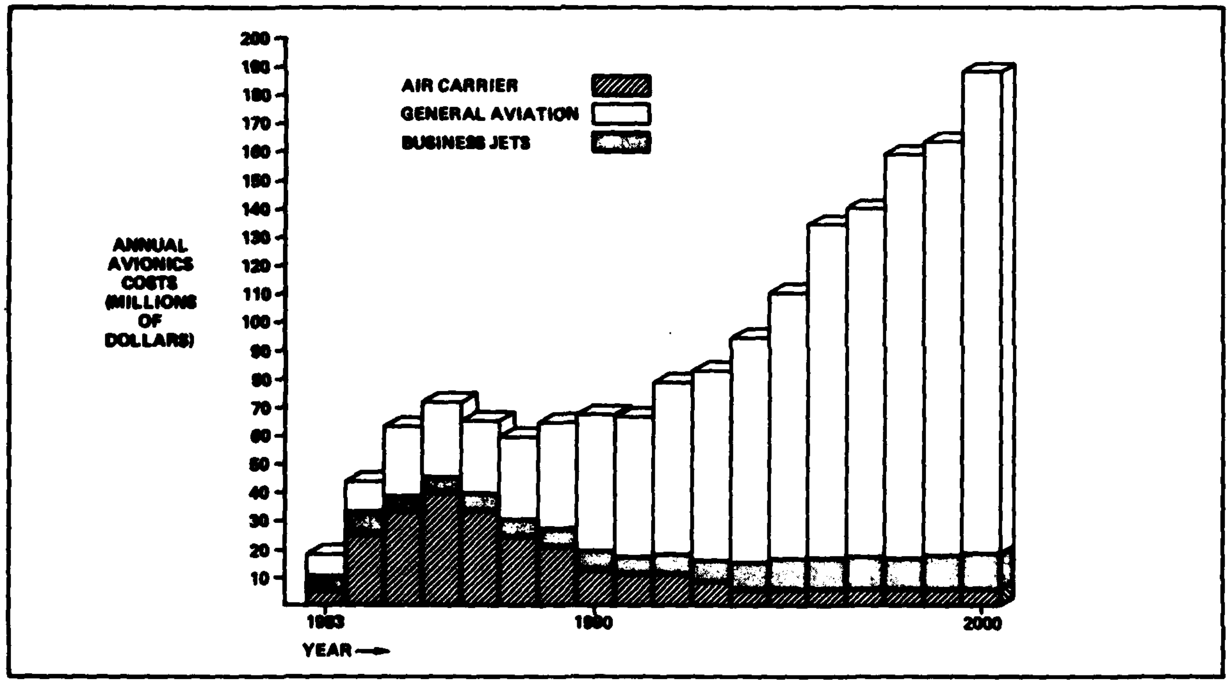

Figure 25. Annual Cost of RNAV Avionics by Aircraft Type (Undiscounted 1983 Dollars)

[35] U.S. Department of Transportation, Federal Aviation Administration, *Implementation of Area Navigation in the National Airspace System*, Final Report, FAA RD-76-196, December 1976, Chap. 5. [Hereinafter *RNAV Study*.]

[36] Estimated times are based on discussions with Headquarters ATC personnel.

[37] *Op. cit., RNAV Study*.

avionics. The totals are not cumulative from year to year.

Given the component costs, the total estimated discounted costs for the Random Routes aspect of an RNAV Integration program are between $538 and $676 million. These are shown in Figure 26.

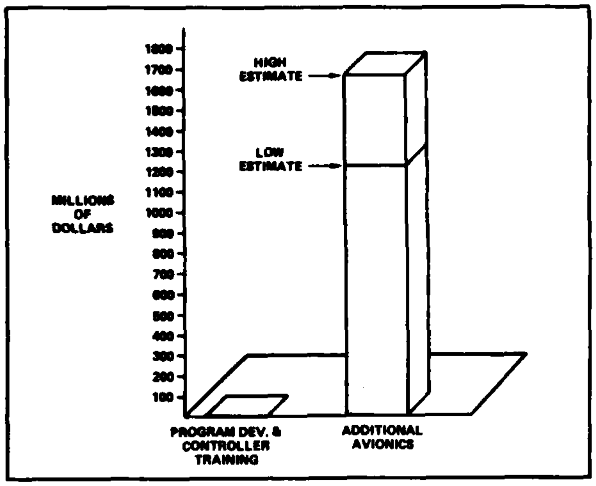

Figure 26. Total Discounted RNAV Integration Costs (1983 Dollars)

Figure 27 graphically depicts the benefit-to-cost ratio of 2.29 to 1.00 estimated for this effort.

This benefit-to-cost ratio was calculated using the low cost, low benefit and high cost, high benefit as follows:

low benefit	=	$1521 million	=	2.83
low cost	=	$538 million		
high benefit	=	$1547 million	=	2.29
high cost	=	$676 million		

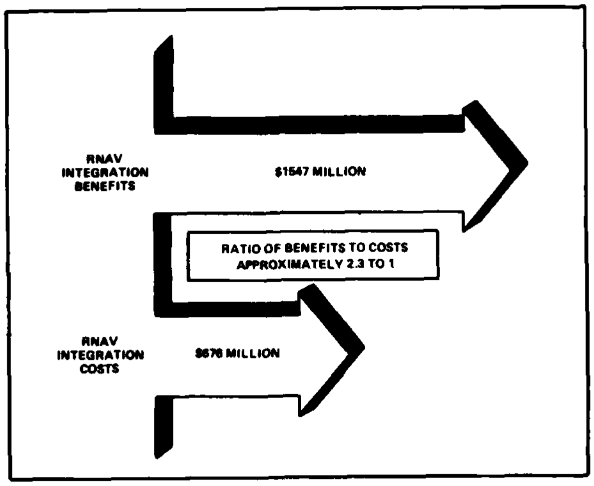

Figure 27. Benefit-Cost Ratio of RNAV Integration Enhancement Area

As can be seen the higher ratio is derived using the lower values. This directly reflects the increasing gap between percent RNAV equipped and percent utilization during the early stages of a random routes program. Indirectly, this may reflect the probability that, as random route utilization increases in the lower altitude strata, the benefits of reduced fuel consumption are lower because aviation gasoline is significantly more costly than jet fuel.

INTANGIBLES

Intangible benefits of RNAV Integration include eventual reduction in airway and route inspection/maintenance due to reduced airways and routes in the NAS, and increased pilot in-cockpit navigational awareness.

Intangible costs may include some additional effort by pilots, especially students, in order to utilize an airspace system which permits a choice among substantially different navigational methods.

CHAPTER 6
OTHER ENHANCEMENT AREAS

Seventeen additional enhancement areas have been identified to date for categorization of recommendations. In subsequent updates of this report, these areas will be analyzed in detail and aggregated with the three areas already developed to more accurately reflect NAR Program benefits and costs. These seventeen remaining enhancement areas are as follows.

Terminal

- Terminal Control Area (TCA)
- Radar Services

En Route

- Airways/Routes
- Flow Management

Flight Service System

- Aeronautical Charts
- Flight Information Publications
- Weather
- Flight Service Station

Airspace System Structure

- Infrastructure
- International Interface
- Airspace for Special Use
- Military Training Routes (MTRs)

Regulations and Standards

- Regulatory Simplification
- Regulatory Elimination
- Standards Development
- Separation Standards
- Handbooks

APPENDIX A

SUMMARY OF CURRENTLY QUANTIFIED BENEFITS AND COSTS

FIGURE A-1.
SUMMARY OF CURRENTLY QUANTIFIED ENHANCEMENT AREA BENEFITS AND COSTS

ACTIVITY	DISCOUNTED BENEFITS	DISCOUNTED COSTS	NET BENEFITS
ARSA	\$ 84.5 M	\$ 43.9 M	\$ 40.6 M
ARTCC Resectorization	303 M	12 M	291 M
RNAV Integration: Random Routes	1,547 M	676 M	871 M
Current NAR Program Total	\$1,934.5 M	\$731.9 M	\$1202.6 M

- $\frac{\text{PROGRAM Benefits}}{\text{PROGRAM Costs}} = \frac{1934.5}{731.9} = 2.64$ Benefit/Cost Ratio of Currently Quantified ENHANCEMENT AREAS

NOTE: Net Benefits are discounted benefits – discounted costs.

APPENDIX B

REPRESENTATIVE

TASK GROUP MEETING AND NAR PROGRAM COSTS

FIGURE B-1.
NAR PROGRAM AND TASK GROUP MEETING REPRESENTATIVE COSTS (1983 DOLLARS)

FAA			
Labor:			
	• 4 People X $226.08/dy[1] X 6[1] dys =	$ 5,426	
Travel:			
	• 2 People (from eastern half of U.S.) at $400 round trip	$ 800	
	• Per diem $75/dy for 8 dys (includes weekend)	600	
		1,400	
Pre/Post Meeting Activities[2]:			
	• 65 dys @ $226.08/day	$14,695	
Subtotal (FAA)			$ 21,521
NARAC MEMBERS			
Labor:			
	• 8 People X $280[3]/dy X 6 dys	13,440	
Travel:			
	• 1 person (from mid-U.S.) at $500 round trip	500	
	• Expenses ($100/dy) X 8 dys	800	
	• Local Travel at $.20/mi for 10 mi for 6 dys X 9 people	108	
	NARAC Travel (total)	$ 1,408	
Pre/Post Meeting Activities:			
	• 3 dys @ 280/dy	6,720	
Subtotal (NARAC Members)			$ 21,568
TECHNICAL SUPPORT			$ 45,300
(Pre-meeting materials, daily summary minutes, staff studies, recommendations classification, automated recommendations tracking, computer support, EXCOM meetings, etc.)			
RELATED NAR STAFF ACTIVITIES[4]		$5,990	
TOTAL (meeting)			$94,379

[1] Based on GS14, Step 5 average salary plus 26 percent fringe benefits. Average meeting duration: 6 working days.

[2] Includes all meeting preparation activities, post-meeting report preparation, preparation of NARAC materials, EXCOM materials, and Administrator briefing, and FAA member/participant reviews.

[3] $55,000/yr X 1.26 (Fringe Benefits)/250 dys per yr = $280/dy.

[4] Averages all other NAR-related activities including travel to and participation by NAR staff in meetings and conferences held by interest groups involved in the NAR; preparation of briefings and papers for such events.

APPENDIX C

ARSA PROGRAM

BENEFITS AND COSTS

FIGURE C-1.

MIDAIR COLLISION COSTS—GENERAL AVIATION—PER AIRCRAFT (THOUSANDS OF 1983 DOLLARS)

		FATALITIES AND INJURIES					AIRCRAFT DAMAGE					
		Fatalities		Serious Injuries			Destroyed			Substantially		
General Aviation	No. of Occupants[1]	Probe[2]	Cost ($653[3])	Prob[2]	Cost ($47[4])	Prob[2]	Replace Value	Exp. Cost	Prob[2]	Restor[3] Value	Exp. Cost	Collision Costs. X Total of Hours Flown[5]
Jet	4.1	.406	$1,087	.046	$ 9	.493	$1,964	$968	.400	$654	$262	2,326 X .03 = $70
Turboprop	5.6	.406	1,485	.046	12	.493	768	379	.400	256	102	1,978 X .06 = 119
Multi-Engine Piston	3.6	.406	954	.046	8	.493	126	62	.400	42	17	1,041 X .17 = 177
Single-Engine Piston	2.2	.406	583	.046	5	.493	33	16	.400	11	4	608 X .67 = 407
Rotorcraft	2.4	.406	636	.046	5	.493	91	45	.400	31	12	698 X .07 = 49
												$822 X 2 aircraft = $1,644

[1] *General Aviation and Aircraft Activity Report*, FAA-MS-79-7, Office of Management Systems, December 1979.

[2] *Annual Review of Aircraft Accident Data, U.S. General Aviation, 1969-1978* National Transportation Safety Board.

[3] *Economic Values for Evaluation of FAA Investment and Regulatory Programs*, U.S. DOT, FAA, Office of Aviation Policy and Plans, September 1981, pg. 40.

[4] *Op. Cit., Economic Values*, pg. 2729.

[5] *FAA Aviation Forecasts*, FY 1983-1994, U.S. DOT, FAA, Office of Aviation Policy and Plans, February 1983.

FIGURE C-2.
BENEFITS OF REDUCED VFR SEPARATION STANDARDS IN ARSA (BASED ON AVERAGE ARSA: 1983 DOLLARS)[1]

Year	Annual Delay Reduction (hrs.)	Total Annual Cost Avoidance	Number of ARSA Locations (arpts.)
1984	312	28,062	2
1985	4,914	441,990	30
1986	12,899	1,160,158	75
1987	25,102	2,257,668	139
1988	26,357	2,370,552	139
1989	27,675	2,489,079	139
1990	29,059	2,613,533	139
1991	30,512	2,744,210	139
1992	32,037	2,881,420	139

[1] Based on the following formula:

60 ops/dy X 3 dys/wk X 52 wks/yr = 9360 ops./yr/ARSA
9360 ops./yr X 1/60 hrs/ops. = 156 hrs/yr/ARSA
156 hrs/yr X 89.94 var-op-cst/hr(GA) = $14,031/yr/ARSA
(Operations assumed to increase by five percent per year)

FIGURE C-3.
SUMMARY OF ARSA PROGRAM BENEFITS (DISCOUNTED 1983 DOLLARS)

Year	Annual ARSA Ops. (# of Sites)	Avg. Ops. Per ARSA (10^5)	MACs Averted	GA Cost Per MAC	MAC Cost Avoidance	VFR Sep. Stan. Cost Avoidance	Total Cost Avoidance	Discount (10%)	Discounted Value
1983	–	–	–	1.644M	–	–	–	1.00	
1984	460,000(2)	2.3	.242	1.644M	397,563	28,062	425,625	.91	387,319
1985	4,080,018(30)	1.3	1.299	1.644M	2,135,427	441,990	2,577,417	.83	2,139,256
1986	12,398,218(75)	1.65	4.988	1.644M	8,199,699	1,160,158	9,359,857	.75	7,019,893
1987	24,127,015(139)	1.74	10.171	1.644M	16,721,250	2,257,668	18,978,918	.68	12,905,664
1988	25,331,216(139)	1.82	11.028	1.644M	18,130,460	2,370,552	20,501,012	.62	12,710,627
1989	26,599,940(139)	1.91	12.029	1.644M	19,776,090	2,489,079	22,265,169	.56	12,468,494
1990	27,929,937(139)	2.01	13.187	1.644M	21,678,700	2,613,533	24,292,233	.51	12,389,038
1991	29,326,432(139)	2.11	14.391	1.644M	23,658,590	2,744,210	26,402,800	.47	12,409,316
1992	30,792,753(139)	2.22	15.769	1.644M	25,924,830	2,881,420	28,806,250	.42	12,098,625
Total			83.104				153,609,281		84,458,232

FIGURE C-4.
COSTS OF INCREASES IN DELAYS (BASED ON ARSA AVERAGE; 1983 DOLLARS)

Year	Number of ARSA Locations	VFR Departure Delay Increase[1]	Total Annual Dollar Costs	VFR Arrival Sequencing Delay Increase[2]	Total Annual Dollar Costs	Entry Delay Increase[3]	Total Annual Dollar Costs
1984	2 arpts.	720 hrs.	$ 42,444	624 hrs.	$ 56,123	260 hrs.	$ 23,384
1985	30 arpts.	11,340 hrs.	668,493	9,825 hrs.	883,661	4,095 hrs.	368,304
1986	75 arpts.	29,768 hrs.	1,754,794	25,799 hrs.	2,320,362	10,749 hrs.	966,765
1987	139 arpts.	57,928 hrs.	3,414,829	50,202 hrs.	4,515,191	20,917 hrs.	1,881,307
1988	139 arpts.	60,823 hrs.	3,585,494	52,712 hrs.	4,740,952	21,963 hrs.	1,975,372
1989	139 arpts.	63,863 hrs.	3,764,724	55,348 hrs.	4,977,999	23,062 hrs.	2,074,141
1990	139 arpts.	67,057 hrs.	3,952,960	58,116 hrs.	5,226,899	24,215 hrs.	2,177,848
1991	139 arpts.	70,410 hrs.	4,150,608	61,021 hrs.	5,488,244	25,426 hrs.	2,286,740
1992	139 arpts.	73,930 hrs.	4,358,188	64,072 hrs.	5,762,656	26,696 hrs.	2,401,115

[1] Based on following formula:

- .3 operations affected x 200 operations/dy x 360 dys/yr = 21,600 ops/yr./ARSA
- 1/60 hr./operation x 21,600/yr = 360 hrs./yr./ARSA
- 360 hr/yr x $58.95 crew cost/hr. = $21,222/yr./ARSA

[2] Based on following formula:

- 60 arr ops/dy x 4 dys/wk x 52 wks/yr = 12,480 ops/yr./ARSA
- 1.5/60 hrs./op x 12,480 ops/yr = 312 hrs./yr./ARSA
- 312 hrs./yr x 89.94 var op cst (ga) = $28,061/yr./ARSA

[3] Based on following formula:

- 50 ops/wk x 52 wks/yr = 2,600/yr.
- 2,600 ops/yr x 3/60 hr./op = 130 hr/yr.
- 130 hrs./yr x $89.94 voc (ga)/hr = $11,692

FIGURE C-5.
OPERATIONAL CONFIRMATION,
TRAINING AND EDUCATION
PROGRAMS COST
PROGRAM TOTAL (1983 DOLLARS)

OPERATIONAL CONFIRMATION (Study design, survey data collection, evaluation support; 1984)	$500,000
TRAINING & EDUCATION	
$20,000 PER ARSA SITE (Based on APO study)	
• 2 (in 1984) x $20,000:	$40,000
• 28 (in 1985) x $20,000:	$560,000
• 45 (in 1986) x $20,000:	$900,000
• 64 (in 1987) x $20,000:	$1,280,000
TOTAL	$3,280,000

FIGURE C-6.
SUMMARY OF ARSA PROGRAM COSTS
(DISCOUNTED 1983 DOLLARS)

Year	NAR Program	Train'g & Educ.	VFR Dep. Delay	VFR Arr. Seq'g Delay	VFR Entry Delay	ARSA Total	Discount (10%)	Discounted Value
1983	$188,658					$ 188,658	1.00	$ 188,658
1984		$ 540,000	$ 42,444	$ 56,123	$ 23,384	$ 161,951	.91	602,375
1985		560,000	668,493	883,661	368,304	2,480,458	.83	2,058,780
1986		900,000	1,754,794	2,320,362	966,765	5,941,921	.75	4,456,441
1987		1,280,000	3,414,829	4,515,191	1,881,307	11,091,327	.68	7,542,102
1988			3,585,494	4,740,952	1,975,372	10,301,818	.62	6,387,127
1989			3,764,724	4,977,999	2,074,141	10,816,864	.56	6,057,444
1990			3,952,960	5,226,899	2,177,848	11,357,707	.51	5,792,431
1991			4,150,608	5,488,244	2,286,740	11,925,592	.47	5,605,028
1992			4,358,188	5,762,656	2,401,115	12,521,959	.42	5,259,223
TOTAL								$43,949,609

APPENDIX D

ARTCC RESECTORIZATION

BENEFITS AND COSTS

FIGURE D-1.
LABOR AND EQUIPMENT COST
AVOIDANCE FROM RESECTORIZATION
(1983 DOLLARS)[1]

Year	Labor Cost Avoidance	Equip. Cost Avoidance	Annual Total
1983	$13,820,375[2]	$ 5,136,750	$18,957,375
1984	55,282,500	15,410,250[3]	70,692,750
1985	55,282,500	0	55,282,500
1986	55,282,500	0	55,282,500
1987	55,282,500	0	55,282,500
1988	55,282,500	0	55,282,500
1989	55,282,500	0	55,282,500
1990	55,282,500	0	55,282,500

[1] Based on the following formulas:

Manpower
[avg. 11.7 controllers/sector @ $35,000]
11.7 x $35,000 x 135 sectors = $55,282,500.

Equipment
[1 PVD/sector @ $152,000/sector]
$152,200/sector x 135 sectors = $20,547,000

[2] Twenty-five percent of maximum annual labor and equipment cost avoidance realized in first year.

[3] Remaining seventy-five percent of equipment cost avoidance realized in second year. Amortization over a longer period not warranted because of pre-resectorization need to replace PVDs in near term rather than over an extended period.

FIGURE D-2.
COSTS OF IMPLEMENTING ARTCC RESECTORIZATION PROGRAM (1983 DOLLARS)[1]

Program Development, sector re-design, briefings, reviews: 1103 mandays	
1103 mn-dy x 193.25[2]/mn-dy =	$213,155
Implementation (Indianapolis Center Consolidation Staff Study estimate)	
46,000 to 66,000 mn-dy x $193.2 =	$8,889,500 - $12,754,500
Travel[3] /$70,000 x 1.055 (CPI increment)) =	$73,850
Equipment	
• Video Maps ($500/ARTCC) =	$20,000
• Sector relocation/reallocation ($8,000/Sector; 135 Sectors Total)	
1982: 34 Sectors (at year end) x $8,000/Sector =	$272,000
1983: 101 Sectors (at year end) x $8,000/Sector =	$808,000
Total Costs (Undiscounted)	$10,276,505 to $14,141,505

[1] AAT-300 memorandum summarizing headquarters and field studies estimating Resectorization Program costs, May, 1982.

[2] Based on 1982 average $183.18 per specialist per day multiplied by CPI average increase of 5.5 percent.

[3] Travel funds provided by NAR budget.

FIGURE D-3.
SUMMARY OF BENEFITS AND COSTS: ARTCC RESECTORIZATION

Years	Annual Benefits	Discount	Discounted Value	Annual Costs	Discount	Discounted Value
1982				9,468,505–		13,333,505
1983	18,957,375	1.00	18,957,375	808,000	1.00	808,000
1984	70,692,750	.91	64,330,402	0	.91	0
1985	55,282,500	.83	45,884,475	0	.83	0
1986	55,282,500	.75	41,754,872	0	.75	0
1987	55,282,500	.68	37,996,933	0	.68	0
1988	55,282,500	.62	34,577,209	0	.62	0
1989	55,282,500	.57	31,465,260	0	.57	0
1990	55,282,500	.51	28,633,386	0	.51	0
TOTAL			$303.6 M			$10.28–14.14 M

APPENDIX E

RNAV INTEGRATION: RANDOM ROUTES

BENEFITS AND COSTS

FIGURE E-1.
ESTIMATES OF AIRCRAFT EQUIPPAGE LEVELS (RNAV AVIONICS) AND RNAV OPERATION RATES, 1983-2000

	Air Carrier		General Aviation			
			Business Aircraft		Other GA	
Year	% Equipped	% Use (RNAV)	% Equipped	% Use (RNAV)	% Equipped	% Use (RNAV)
1983	12	8	6	1	6	1
1984	25	13	7	2	7	2
1985	40	25	9	4	9	4
1986	60	45	11	5	11	5
1987	75	60	13	6	13	6
1988	85	68	15	8	15	8
1989	92	75	21/21+	15/17	21/21+	15/17
1990	95	80	23/24	16/18	23/24	16/18
1991	97	82	24/26	17/20	24/26	17/20
1992	99	84	26/29	18/22	26/29	18/22
1993	100	87	28/32	19/24	28/32	19/24
1994	100	89	32/38	27/32	32/38	27/32
1995	100	90	34/42	29/35	34/42	29/35
1996	100	92	36/47	31/38	36/47	31/38
1997	100	93	38/53	33/44	38/53	33/44
1998	100	94	42/60	36/50	42/60	36/50
1999	100	95	46/67	40/57	46/67	40/57
2000	100	96	51/75	44/65	51/75	44/65

FIGURE E-2.
ESTIMATED RANDOM ROUTES FUEL CONSUMPTION SAVINGS 1983-2000 (1983 DOLLARS)[1]

Year	Cost Savings (millions)	Discount Factor	Discounted Value (millions)
1983	17.77	1.00	17.77
1984	30.21	.91	27.49
1985	59.39	.83	49.29
1986	107.02	.75	80.23
1987	145.16	.68	98.71
1988	169.80	.62	105.28
1989	196.81/198.24	.56	110.21/111.01
1990	214.44/215.92	.51	109.36/110.12
1991	227.12/229.47	.47	106.75/107.85
1992	240.19/143.45	.42	100.88/102.25
1993	256.65/260.93	.39	100.09/101.76
1994	278.79/283.24	.35	97.58/99.13
1995	294.77/300.33	.32	94.33/96.11
1996	314.67/321.41	.29	91.25/93.21
1997	332.50/343.52	.26	86.45/89.32
1998	352.19/366.82	.24	84.53/88.04
1999	374.18/392.59	.22	82.32/86.37
2000	393.63/417.27	.20	78.73/83.45
			1521.25/1547.39

[1] Dollar cost savings were derived using the following formula in each year:

Estimated gallons used by A/C x estimated RNAV utilization rate (see Figure E-1) x 2.5 percent x $1.00/gal. = A/C fuel savings

Estimated gallons used by GA x estimated RNAV utilization rate (see Figure E-1) x 2.5 percent x $2.05/gal. = GA fuel savings

A/C savings + GA savings = Total annual fuel savings

FIGURE E-3.
RANDOM ROUTES RNAV PROGRAM
DEVELOPMENT COSTS
(1983 DOLLARS)

NAR Meeting:	$94,379
HQ & Regional Staff:	
Program Development and Review (HQ) (230 mn.-dys @ $225/dy) =	$51,750
(1/2' 1983; 1/2 1984)	
Program Reviews and Briefings (Regions) (30 mn.-dys $225/dy) =	$6,750
(1/2' 1983; 1/2 1984)	
Subtotal Program Development =	$152,879

FIGURE E-4.
CONTROLLER RNAV TRAINING COSTS
(1983 DOLLARS)[1]

- New Controller Training:
  - [additional 5 hrs. at Okla. City Training Center per controller trainee ($16.25/hr)[2]; FAA trainer ($28.25/hr)[3]]
  - 5 hrs. x $10.43/hr x 500 controllers/yr = $26,075
  - 5 hrs. x $28.25/hr x 25 trn'g classes/yr = $3,531

  $29,606/yr.
  (each year of program)

  SUBTOTAL

- Re-training for RNAV
  - 45% of controllers each require 3 hrs. training
  - total trainer time = 1mn.-yr
    - 5000 controllers x 3 x 23.02/[4]hr. = $345,300
    - 1 FAA mn-yr = $117,000

  SUBTOTAL $462,300 (1984 only)

---

[1]Hour estimates based on Headquarters ATC personnel judgment.

[2]GS 7 entry level plus 26 percent fringe benefits.

[3]GS 14 average plus 26 percent fringe benefits.

[4]$38,000 per year average controller salary plus 26 percent fringe benefits.

FIGURE E-5.
COSTS OF RNAV AVIONICS TO AIR CARRIERS AND GA OPERATORS, 1983-2000

Year	Number of A/C Aircraft Equipped[1]	Cost[2] (000)	Number of Bus. Jet Aircraft Equipped[1]	Cost[3]	Number of GA Aircraft Equipped[1]	Cost[4]	Total Cost (Undiscounted)
1983	60	4,878	750	5,625	1350	8,438	18,941
1984	331	26,910	750	5,625	1763	11,019	43,554
1985	395	32,114	800	6,000	4043	25,269	63,383
1986	480	39,024	800	6,000	4280	26,750	71,774
1987	412	33,496	800	6,000	4400	27,500	66,996
1988	298	24,227	800	6,000	4690	29,313	59,540
1989	251	20,406	850/950	6,380/7,130	5050/6125	31,563/38,281	58,349/65,817
1990	152	12,358	850/950	6,380/7,130	5150/7697	32,188/48,106	50,926/67,594
1991	127	10,325	850/950	6,380/7,130	5350/8048	33,438/50,300	50,143/67,755
1992	131	10,650	900/1000	6,750/7,500	6600/9800	41,250/61,250	58,650/79,400
1993	105	8,537	950/1000	7,130/7,500	8400/10,978	52,500/68,613	68,167/84,650
1994	70	5,866	950/1100	7,130/8,250	8702/12,941	54,375/80,881	67,193/94,819
1995	70	5,866	1000/1200	7,500/9,000	9096/15,106	56,850/94,413	70,038/109,101
1996	70	5,866	1000/1500	7,500/11,250	9450/18,872	59,100/117,950	72,288/134,888
1997	70	5,866	1000/1500	7,500/11,250	9816/19,535	61,350/122,094	74,538/139,032
1998	70	5,866	1100/1500	8,250/11,250	13,601/22,577	85,006/141,106	91,519/158,044
1999	70	5,866	1200/1600	9,000/12,000	13,981/23,316	87,381/145,725	102,069/163,413
2000	70	5,866	1300/1800	9,750/13,500	15,846/27,063	99,038/169,144	114,476/188,332
TOTAL							1,202,544/1,677,033

[1] *Number to be equipped is based on the following formula:*
Total aircraft (by type) projected x percent RNAV equipped (see Table D-1).
Projections derived from FAA Aviation Forecasts FY 1983-1994, pg. 29 (air carrier) and pgs. 16 and 17 (business jet and general aviation).
Projections for 1995-2000 based on straight line extrapolation.

[2] \$81,300 per aircraft; RNAV Study, p. 5-22. Study figure was inflated to reflect increase from 1976 to 1983.
[3] \$7,500 per aircraft; RNAV Study, p. 5-22. Inflated to 1983.
[4] \$6,250 per aircraft; RNAV Study, p. 5-23. Inflated to 1983.

FIGURE E-6.
SUMMARY OF COSTS FOR RANDOM ROUTES ASPECT OF RNAV INTEGRATION
DISCOUNTED 1983 DOLLARS)

Year	Program Dev.	Controller Training	Additional Avionics (000)	Total (000)	Discount	Discounted Value (000)
1983	123,629		18,941	19,065	1.00	19,065
1984	29,250	491,906	43,554	44,075	.91	40,108
1985		29,606	63,383	63,413	.83	52,633
1986		29,606	71,774	71,804	.75	53,853
1987		29,606	66,996	67,026	.68	45,578
1988		29,606	59,540	58,638	.62	36,356
1989		29,606	58,349/65,817	58,379/65,847	.56	32,692/36,874
1990		29,606	50,926/67,594	50,956/67,624	.51	25,988/34,488
1991		29,606	50,153/67,594	50,173/67,784	.47	23,581/31,858
1992		29,606	58,650/79,400	58,680/79,430	.42	24,646/33,361
1993		29,606	68,167/84,650	68,207/84,680	.39	26,601/33,025
1994		29,606	67,193/94,819	67,223/94,849	.35	23,508/33,197
1995		29,606	70,038/109,101	70,068/109,131	.32	22,422/34,922
1996		29,606	72,288/134,888	72,318/134,918	.29	20,927/39,126
1997		29,606	74,538/139,032	74,568/139,062	.26	19,388/36,156
1998		29,606	91,519/158,044	91,549/158,074	.24	21,972/37,938
1999		29,606	102,069/163,413	102,099/163,443	.22	22,462/35,957
2000		29,606	114,476/188,332	114,506/188,362	.20	22,901/37,672
Totals						538,222/675,689